UNITED STATES DEPARTMENT OF AGRICULTURE

FOREST SERVICE

REPORT OF
RANGE RESEARCH CONFERENCE
AT
INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION
GREAT BASIN BRANCH, EPHRAIM, UTAH
AUGUST 17-30, 1931.

F.S. RECEIVED SEP 22 1932 GRAZING

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The meeting was sponsored by the Ecological Society of America and held for the purpose of discussing range research with particular attention to methods. The program was planned to give opportunity for field discussions and demonstrations as well as general meeting discussions. The committee in charge of arrangements consisted of: C. L. Forsling, chairman; H. C. Hanson, Walter P. Taylor, and W. G. McGinnies, secretary.

After a brief welcome by the chairman followed by a speech outlining the interest of the Ecological Society, by President A. O. Weese of the Society, the various subjects were taken up individually.

In presenting this report an effort has been made to include all prepared papers submitted, at least so far as they refer to methods, and the more pertinent discussion of which there is a record. (Ed.)

SUBJECT I: METHODS OF STUDYING PLANT POPULATIONS AND THEIR CHANGES

Herbert C. Hanson, Chairman

RANGE SURVEYS

W. G. Koogler: INTENSIVE RANGE RECONNAISSANCE. In making intensive range surveys, it is vitally necessary to procure prints of the best available topographic or other detailed maps that it is possible to obtain for use in the field. Where there is no base map available or where it is of insufficient accuracy or detail as to serve satisfactorily, then a map must be made of the area being considered for the survey either in advance of the actual reconnaissance work or in connection with it. The broken contour or form line system of mapping, made by triangulation will usually meet our needs satisfactorily and this method greatly facilitates the work when both reconnaissance and mapping are being carried on at the same time.

In carrying on intensive range classification the area should ordinarily be covered on the basis of passing twice through a section and mapping 20 chains on either side of the traverse line and making such offsets as may be needed to obtain the needed information on all types and to properly map their boundaries. Intensive reconnaissance types to a minimum of 10 acres. If the work is carried on with a good topographic map the examination may be made by drainage and exposures but should be no less intensive.

The dominant vegetation cover is the governing factor in type classification and standardized numerical numbers are set up as a simple means of classifying and designating the various types that may be encountered. The symbols and colors for the types are given in detail in Ref. No. 1 below.

Where changes occur in type values subtyping is done to obtain more accurate data for determining carrying capacity. Factors which necessitate subtyping within a major type are changes in density, composition of vegetation, aspect, soil, etc.

In connection with the typing work which can usually be done more satisfactorily on foot than on horseback, especially where the work is intensive, a type writeup or vegetation record is also prepared for each type or subtype entered on the map. A special form (Form 764a) is used by the Forest Service for making type writeups on intensive or extensive reconnaissance. This writeup, in a broad sense, amounts almost to a belt transect vegetative record and lists all of the more important vegetation by classes and species together with the examiners estimate as to the percentage of the total cover occupied by each. By multiplying the percentage figure credited to each species making up the stand by a predetermined palatability figure for the species and adding all of the results together for any given type the average or type palatability is obtained.

(Over)

This result is then in turn multiplied by the type density, or total available forage cover as expressed in terms of the percentage that the actual type cover bears to a perfect or 100% cover, in order to obtain the forage acre factor for the type involved.

Since the purpose of the reconnaissance is to furnish basic information for the development of range management plans, in addition to the type map and forage data thus procured, reconnaissance also records all matters pertinent to the requirements and proper management of the range, such as, current utilization, range waters, fences and improvements, desirable salt locations, seasonal use recommendations, areas infested with rodents or poisonous plants, game and erosion conditions and such other influencing factors as may have an important bearing on proper range use.

In the compilation of the work, type acreage is measured with the planimeter. This procedure again emphasizes the importance of accurate base control and the need for correct typing in the field. After determining type acreages each area figure determined is multiplied by its respective forage factor to obtain the forage acres for types. Although the section is usually made the unit for compilation purposes the data concerning surface and forage acres are also summarized by townships, allotments and divisions as comprising more usable units for administrative use.

D. A. Shoemaker: EXTENSIVE RANGE RECONNAISSANCE. The chief differences between intensive and extensive reconnaissance are that intensive reconnaissance types to a smaller acreage and also recognizes variations within the type such as degree of slope, aspect, or soil which influence density and type composition. Extensive reconnaissance is done by men who have been trained on the intensive surveys. Otherwise, the field work and office compilation in connection with extensive range reconnaissance is identical with intensive reconnaissance.

Discussion of Intensive and Extensive Reconnaissance

Koogler - To avoid variations in forage acre factor estimates made by members of crew, one trained man should check each individual's work. Carrying capacity estimates are checked by grazing capacity research and by records of use of allotments from year to year.

C. K. Cooperrider - Research can do much to enhance value of reconnaissance for administrator and user: Reconnaissance gives a picture of condition today. It determines composition, density, and relative value. What the association was, what is it now, and what we want it to be and plan management accordingly.

Forsling - We should know which species we desire to dominate an area.

W. C. Lowdermilk - Litter between the plants, such as dead leaves, twigs, etc., is very important in maintaining fertility of the soil and in preventing erosion. Should litter be considered in reconnaissance work?

Shoemaker - A record is made of slope, erosion, and soil and its condition.

Shoemaker also stated that no attempt is made to standardize intensive and extensive reconnaissance upon the basis of cost per acre. As the vegetation changes due to management additional range improvements, etc., it is necessary to recheck reconnaissance data. This may be done periodically but its necessity will depend upon how rapidly the conditions on the ground change. This recheck can be done by the sample plot method, i.e., examining representative types in order to obtain a correction factor which may be applied to similar types where grazing use and other conditions have been about the same since the original reconnaissance was made. In other words it is not necessary to re-type the range in order to obtain a satisfactory check of the reconnaissance data. The extensive range reconnaissance work in Region 3, (Arizona and New Mexico) is costing about one-third of a cent an acre and that figure includes form-line mapping of most of the country.

References:

1. Anonymous. Instructions for grazing reconnaissance on National Forests. Mimeographed. U.S.Forest Service.

2. Jardine, J. T., and M. Anderson. 1919. Range management on the National Forests. U.S.Dept. Agric. Bul. 790, pp. 74-82.

3. Sampson, A. W. 1923. Range and Pasture Management New York. Chapters 16 and 17.

Craddock: DENSITY METHODS. Density methods of studying plant populations have been used in the West by range investigators more extensively than have those of the frequency type. They lend themselves to the solution of problems where time and the volume of data to be collected are limiting factors. In addition, density methods reflect plant populations in terms of ground cover and in this respect have been well adapted to investigations involving forage values and in the study of watersheds.

The Density Concept

All density methods are based upon the simple concept of ground cover. Density itself usually is referred to as that portion of the ground which is covered by a vertical projection of the foliage of a plant or plants on a given area. Obviously, for single-stalk plants which produce no aerial foliage, density coincides with the actual periphery of the stalk or the space occupied by the plant, on a given site. For all other plants density includes more than the area occupied by basal stems for to this area must

be added the projectional volume of the leaf crown. When crowns are not dense they must be contracted, either mechanically or visually, until the total shaded area is reduced on the ground to a solid unit. In some instances, as with a spreading bush or tree on which the foliage may be concentrated near the ends of the branches, it is convenient to secure the total density of the plant by summing the densities of the bunches of foliage. Density is usually recorded in square centimeters when mapped and plotted and for a given area covered by reconnaissance methods may be referred to in tenths; e.g., a density of 0.5 indicates that half the ground is covered by vegetation.

Mechanical and Estimate Density Methods

There are two general groups of Density Methods. One group embraces a number of systems of plant measurements based on ocular estimates while a second group consists of measurements made by mechanical devices. The former group, or so called estimate methods, depend for their accuracy upon the trained judgment of examiners. The mechanical methods function largely with the aid of such instruments as the circular and linear rules, or, more commonly, the chartograph. The use of such devices increases the accuracy of plant measurements but, - at the expense of time. Estimate methods have been used most extensively in connection with grazing surveys over large areas but the principle also has been applied to the measurement of various kinds of small plots. The estimate method as used in range surveys has been described in U. S. D. A. Bulletin 790 and further details are given in the range management sections of the various regional Forest Service handbooks. The mechanical methods have been adapted to various types of plots likewise, of which the meter quadrat, as measured by the chartograph, is perhaps the most common example.

THE "BOISE" MAJOR-PLOT METHOD.

By

F. G. Renner and C. K. Pearse

In determining the density and composition of the vegetation on small areas, it has been the common practice to follow the ocular method commonly used in the ordinary range survey. In using this method, the species are listed, their densities estimated, and these values added to give the total density of the vegetative cover on the plot; or - the total density of the entire plot is first estimated and the percentage of each species determined in terms of the total cover.

In our studies on the Boise watershed the ocular method has not resulted in data of sufficient accuracy, nor has it supplied all of the information felt needed. On the Boise, a considerable number of species, differing widely in their habits of growth, are commonly found associated on small areas. These plants include such large "clump-formers" as wheatgrass, balsamroot, loco, and lupine; plants like yarrow and Aconogonum which form sparse bunches; and a number of smaller plants of which Sandberg's

bluegrass, melic-grass, and false yarrow, are typical. Due to this variety in the form of the vegetation, considerable difficulty was experienced in securing satisfactory estimates of density. Even on areas as small as 5 x 5 meter major plots, almost regardless of the care taken, estimates of the density by the usual ocular method invariably resulted in figures much higher than those from an actual charting of a sample meter-quadrat.

In addition to the lack of agreement with measured densities and inaccuracies due to inexperienced and changing personnel, the ocular estimate method fails to give much detailed information desirable in connection with certain studies. Investigation into the effect of the vegetative cover upon erosion have shown the total density of the vegetation, or even the total density by species, to be insufficient. Two areas may be found nearly identical in these respects, but uneroded in one case, and eroding in the other. The reason may be found in the fact that on the uneroded area the density is made up of a large number of small plants, while on the other, a fewer number of large plants of the same species and with the same total density, are unable to prevent the formation of incipient shoestring gullies. The number of plants on the area, and their range in size, may be as important or even more so, than their total density.

To more nearly approach the accuracy of results secured by the pantograph on meter-quadrats, but without a corresponding increased expenditure of time, and to secure the additional detailed information felt necessary, the present method of actually measuring the projected area of the vegetation, by species and individual plants, was developed. The data were recorded on a special form which provides for recording the number of each species by each size class as recorded on the field measuring scale.

At the outset, an ordinary half-meter scale was used. Actual measurements, in centimeters, were made of the individual plants at their greatest and smallest diameters and the average diameter thus obtained and recorded. The records were kept on a form which segregated, by species, the range in diameter classes from 1 centimeter, - upwards. Upon completion of the seasons' field work, the actual area for each individual plant; for all plants of a single species; and of the total vegetation on the plot, was obtained. This system of recording diameters and later converting them into areas necessitated considerable office compilation which was eliminated by the construction of a scale to be used in the field, from which the area in square centimeters might be read directly. As now used, it is possible by direct measurement to record in the field the areas of individual plants ranging in size from two tenths of a square centimeter to 2,000 square centimeters, or larger.

In practice the 5 x 5 meter major-plot is subdivided by tape into five strips, each 1 x 5 meters in size. The presence of small gullies or other minor topographic features, or slight changes in the character of the vegetation, as well as convenience in mapping make it desirable to divide the major-plot in this manner. Records are kept for each of these strips, which, when totaled, furnish the data for the entire plot. This method is particularly adapted to study of the type of vegetation characterized by a moderate number of plants on an area, and to plots where accurate ocular

estimates are difficult to attain on account of wide differences in the size of the plants and other growth habits. On areas where the vegetative cover is dense and made up of a great number of small plants, the added time required might preclude the use of the method. Even here, the increased accuracy as well as the additional information secured might justify the greater expenditure of time.

Summary. The limitations and advantages of the method herein described may be briefly summarized as follows:

Limitations. 1. Under conditions of dense vegetation made up of a great number of small plants, the use of this method would necessitate the expenditure of considerable time.

2. Inaccuracies due to the personal factor are still present, although less important than with the ocular method.

Advantages. 1. Increase in accuracy over the ocular estimate method.
(a) Less need for experience and judgment and decrease in personal error.
(b) Density measured to three decimal places instead of estimated to two places.

2. More data obtained than with the ocular estimate method.
(a) Better information on just what changes in growth of plant cause changes in density.
(b) Better life history data on species involved.
(c) Information secured on the number of seedlings produced and becoming established.
(d) Data obtained on the size ranges of individual plants.

QUADRATS

Methods Used in Studying Herbaceous Vegetation and its Change

Herbert C. Hanson

Kind of quadrat to use is determined by the purpose of the investigation and by the kind of vegetation.

Kinds of quadrats: (1) pantograph-chart, (2) count-list, (3) density-list, (4) area-list, (5) weight-list. See Ecology 11:734-748. 1930.

Count list quadrats form basis for frequency studies. See Ecology 9:467-473. 1928. and Journ. Agric. Res. 41:549-560. 1930.

Best time of year to quadrat in northern Colorado is latter half of June. Early spring plants are still present and late summer and fall plants are far enough developed to identify.

Compilation methods: simplify as much as possible. Adding machine used considerably. Avoid use of planimeter as much as possible.

Comparison of same area at different periods; emphasis has been laid upon comparing the abundance of same species in different years, rather than comparing totals of all species.

Comparison of different areas; frequency methods have been found very useful, especially when counts of individuals are made.

Numbers of stalks of use species cannot be compared to areas of another species; as stalks of Agropyron smithii and areas of Bouteloua gracilis.

Demonstration of listing square and of record form including photographs.

Procedure Adopted in Studying Changes in Plant Populations in Mixed Prairie and Irrigated Pastures in Northern Colorado

1. Drive stakes in S. E. and N. W. corners of the quadrat (each one labeled with number of quadrat and corner).

2. Photograph from south on 5 x 7 film. (In rare cases photograph may have to be taken from another direction).

3. Divide quadrat form into 20x20 cm. squares.

4. Secure basal areas of mats, tufts and clumps by means of area-list method, for each 20x20 cm. square. If the area of a clump is 200-400 sq. cm., or greater, the use of the pantograph is very desirable.

5. Count stalks of single or few-stalked plants, for each 20x20 cm. square.

6. If a species usually occurs as a mat, tuft, or clump, always give areas but counts may also be given. (Bulbilis, Aristida, Bouteloua, Stipa, Dactylis glomerata, Festuca elatior, Trifolium spp., Poa pratensis).

7. If a species usually occurs as single or few-stalked plants always give number of stalks, but areas may also be given. (Agropyron smithii, Senecio perplexus, Taraxacum, Bromus inermis, Phleum and most forbs).

8. Form for summarized tabulation of each quadrat:

Location | Quadrat No. | Date

Symbol	Species	Area sqm. cm.	Total no. of stalks	Total no. of seedlings
A	Bouteloua gracilis	340		3
B	Agropyron smithii		530	

Frequency studies are very valuable in determining the composition of the vegetation and for comparing the vegetation in different areas. The size of quadrat depends upon the density and uniformity of the vegetation. In mixed prairie in northern Colorado 2 square meters appeared most satisfactory. The number of samples depends upon the size of the area. The samples should be uniformly distributed over the area. Field records are made upon large sheets of paper ruled in such a way as to take care of at least 10 quadrats per sheet. The adding machine is used in summarizing abundance data.

Craddock: The choice of methods which may be selected to investigate a given plant cover largely depends upon the scope of the studies contemplated and upon the type and complexity of the vegetation. A given method of plant cover analysis may be adequate for one phase of a problem but often it is desirable to use a combination of two or more schemes of measurement in order to bring out several aspects. A prerequisite to any study of plant populations therefore is a thorough preliminary investigation of all usable methods.

Regardless of whether one or more methods are used to study a given problem, it is desirable that they yield data which can be analyzed statistically and, of course, that they yield results within reasonable limits of error. In this connection it is essential that a preliminary determination should be made of the number and size of the plots or samples which will be needed to yield a sufficient quantity of data for statistical analysis. However, the fact that certain data do not lend themselves to an adequate statistical analysis should not prevent the obtaining of significant indications from observation worthy of publication.

Difficulties of Measuring Range Vegetation

Range vegetation, as compared to high forests, is small, highly variable in form and subject to annual fluctuations of climate. To measure individual plants in place and without disturbance is difficult and time consuming. Recurrent measurements over a period of years, to isolate the influence of climate and other factors, entails a careful consideration of the time element as well as that of cost and available personnel. In addition to the limitations of measuring individual plants the difficulties involved in range investigations loom larger when it is remembered that the western ranges cover extensive areas and that a few measurements on small plots may not be sufficient for the study of entire watersheds or other extensive areas.

W. R. Chapline: In answer to the question of value of quadrats, the actual records on quadrat charts makes possible future analysis. On the Jornada and Santa Rita, for example, quadrats are furnishing one big phase of specific data for analysis of changes in vegetation in relation to climate and grazing, as an actual record to supplement more general information in the study of grazing capacity, etc. Area figures alone are not sufficient. Changes are rapid. It has been necessary to study actual changes in specimens on quadrats. An example of this is the considerable

increase in area shown in Rothrock grama between 1918 and 1919. Many of the old tufts decreased or died out as a result of 1918 drought, but numerous seedlings resulting from the favorable growing conditions in 1919, more than offset this loss. Another example is the actual changes in tufts that have occurred as a result of different intensities and periods of clipping. The more we have analyzed the quadrat data and studied the charts, the more value has been shown to be in them. While we have gotten much from analyses already made, I expect the quadrat records now available to be of immense value in future more intensive study and analyses of the range problem.

While the quadrat method is still in the formative stage, the analyses so far made have shown the essential need of chart quadrats of perennial grasses for certain kinds of studies in the Southwest, and have emphasized the advisability of intensification. Annuals, of course, are only listed. The completeness and effectiveness of the supplemental notes deserve utmost consideration.

Craddock: A few uses of the quadrat method are listed to indicate the scope of this method.

The list quadrat is valuable for detecting changes in the composition of a stand, particularly in respect to invading species of single-stalk form. However, since the list quadrat does not locate the individual plants or show their relative sizes this method has its limitations.

The chart method locates each plant and in addition shows its relative density either at the ground line, an inch above the root crown, or at any other height which might seem significant. This method may be used as a measure of succession equally as well as the list method and has the advantage of lending a weighted value to each plant in respect to ground cover. The chart method is particularly useful in correlating plant growth with climatic and other influences. Fluctuations in total density of individual species, the changes in shape of their crowns, as well as their migration by stolens or seedlings are important points brought out by recurrent quadrat chartings. When such density measurements are weighted by fluctuations in height growth a total yield value can be obtained which in turn may be correlated with carrying capacity or other values.

Quadrats may be used for other range investigation purposes such as sites for taking plant development and utilization but technically these other uses are not directly concerned with measurements of plant populations.

A. W. Sampson: The list quadrat in the mapping of annual vegetation has the following advantages over that of the chart quadrat: the work can be done much more rapidly, and the succession on any part of the quadrat can be traced, for the reason that the species occurring within each square decimeter are listed as to identity and numbers--accordingly one has nearly all the data that would be available from the chart quadrat; the time involved in summarizing the data from a list quadrat is appreciably less than for the chart quadrat, because it is necessary only to add up the number of

species as listed in each decimeter; in the annual type of vegetation, under California conditions at least, one or two species almost invariably dominate the area after a few years of protection. With this relatively uniform cover the list quadrat seems particularly suitable. Moreover the cover is generally quite dense so that charting is done with difficulty.

In listing, the pantograph is, of course, not used, but a count is made of each species that occurs within each square decimeter, and these are recorded on the chart in the proper portion concerned on the form, using a symbol followed by a dash and then the number of specimens. Also in each portion of the map representing each square decimeter the density of the cover is given. From these data one can readily work up the palatability and the forage acre factors. See "Range and Pasture Management", pp. 359-359. On page 347 is found a short discussion on the use of the list plot.

The bisect has been used in California to great advantage in obtaining the profile of roots and branches. This method yields enormous detail. Method - A trench is dug deep enough to reach the lowest part of the root. The root and its branches are sketched to scale on a map, sufficient measurements being made to get the average root. Bisects vary in length. They generally run from 10 to 20 ft., however, one of 190 ft. was made.

Matt J. Culley: Various methods of studying the plant population have been used on the Santa Rita Range Reserve and met with varying degrees of success depending upon the type and density of vegetation as well as the character of the season with respect to the climatic conditions, the chief of which is rainfall. For the most part we have dealt with perennial grasses in detail, with estimates or counts of annual grasses and weeds. The density and composition variations of the perennial grasses have been followed largely through the use of meter square quadrats scattered over the range and chosen to represent as nearly average conditions as possible. These have been mapped once each year at the close of the summer growing season and have without doubt given us some valuable information on the general vegetative trends from year to year. As a result of our past quadrat work I have felt that not less than five and preferably ten meter square quadrats should be used for studying any given conditions on the range. In other words, instead of having one quadrat to represent an over-grazed condition in a single locality, we should have at least ten and take an average of the ten to represent a true average condition.

Under the limiting conditions of personnel and finances the use of the chart quadrat has been questioned. Chart quadrats give probably the best information we can get on density variations and, up to densities of .2, will probably be justified when a chartograph is used since experienced chartograph operators can map a meter square quadrat of this density in from 15 to 30 minutes. There is, of course, the question of variation in charting due to changes in personnel. For the last ten years this factor has been eliminated on the Santa Rita by having one man chart all the quadrats throughout that period. The chart quadrat also should be employed to some extent, at least, as a means of checking other methods that may be used.

In 1926 we started a special clipping study on the Santa Rita using meter square quadrats with the ultimate purpose in mind of studying the density trends as well as the actual volume production variation in response to different degrees and frequencies of clipping through the summer growing season. These quadrats were charted both at the beginning and at the end of the growing season and the density phase of the study indicated very clearly that we should have at least two measurements during the year to satisfactorily measure any changes that occur. Many of our largest gains in density were recorded between the end of one summer growing period and the beginning of the next summer period, indicating that there is often a considerable amount of plant activity during the supposedly dormant season. In addition to the density variations the clipping study does give us some rather definite information on the variation in volume production from one year to another which, even though it may not be identical with that which would occur under actual grazing, must be considered as extremely valuable information. Further study of clipped quadrats may enable us to arrive at some methods that will more nearly approach what we have under actual grazing by stock.

Along with actual mapping of quadrats we have recorded certain essential data such as the average height growth of various species, the number of flower stalks produced and the degree of utilization, rodent and other apparent influences, seasonal rainfall distribution, ocular densities on both quadrats and adjacent areas and the apparent vigor of various species.

The essential features of the present chartograph are as follows: (1) a rigid table varying in size to meet the special needs and of laminated construction so as to avoid warping; (2) the legs must be absolutely rigid to prevent movement of the table either horizontally or vertically; (3) the pantograph bars must be swung, rather than supported by a bearing which rolls on either a track or on the table. This makes a much freer moving pantograph that will operate with practically no error at all; (4) we have also used ball bearings in the joints of the pantograph and although they are far from perfect have indicated if the proper bearing could be secured it would practically climate any play whatsoever in the arms.

METHODS OF STUDYING SHRUB PLANTS ON RANGE LANDS

By E. W. Nelson

A. Major plots on grazed and ungrazed range.

1. Location and size of individual plots.

2. Purpose to determine number of plants by species on a given area and the crown spread of the individual plants up to a height of 5 feet.

3. Methods of mapping individual shrub plants at five-year intervals.

   (a) Traverse board.
   (b) Gridiron.

4. Density estimates at two-year intervals.

B. <u>Individual shrub plants.</u>

1. Selection and tagging of 5 shrubs of each important species in the different climatic zones.

2. Purposes.

    (a) To determine annual increment of twigs.
    (b) To determine more accurate measurement of seasonal utilization by livestock.

3. Methods.

    (a) Tagging 1 to 3 large representative stems on each shrub.
    (b) Measurement of all the new growth on each large stem annually to secure total twig growth.
    (c) Remeasurement of remaining twig growth on shrubs on grazed range after utilization by livestock to determine degree of utilization of each shrub species.

C. <u>Supplemental studies.</u>

1. Establishment of hurdle plots to be open to grazing during various grazing periods.

2. Establishment of meter quadrats in each shrub major plot to determine the changes in the herbaceous cover year after year.

Rod square areas usually are large enough for the study of small bushy species but for plants over 60 centimeters high, such as <u>Amelanchier</u>, <u>Prunus</u>, and <u>Quercus</u>, plots of greater dimensions are more desirable.

Two general methods of mapping have been developed. The gridiron scheme of mapping is most useful for mapping small areas whereas the plane table method often is used on plots larger than one rod square. In either case the object of the method is to determine the periphery of the shrubby vegetation, dead centers, or other irregularities and to check the densities of one year with subsequent measurements. Such density measurements should be combined with others of maximum and minimum height growth. For plots in a mixed stand it may be necessary to supplement the browse mapping with ocular or quadrat estimates of the herbaceous vegetation. A discussion of methods for studying shrubby plants in relation to grazing has been reported upon previously by E. W. Nelson in Ecology, Vol. XI, No. 4, Oct., 1930.

INVESTIGATIONS ON NATURAL OR PRIMITIVE RANGE AREAS

Outline by G. D. Pickford

A. Object of Study.

1. To determine quickly, the potential plant cover of different types at various elevations and on different sites.

2. To draw comparisons of the vegetative cover in regions where improper grazing practice or promiscuous burning has evidently decreased the carrying capacity of the range.

3. To trace plant succession and to affix climax types to areas more or less depleted.

B. Methods.

1. Location.

   a. Cemeteries.
   b. Old dry farms.
   c. Inaccessible areas.

2. History.

   a. Manner of protection.
   b. Length of time practiced.
   c. Grazing history.
   d. Burning history.

3. Composition.

   a. Total density.
   b. Percentage of species.
   c. Palatability of species.
   d. Forage factor.

4. Comparison with similar utilized areas.

   a. Grazed areas.
   b. Burned areas.
   c. Grazed and burned areas.

5. Analysis of data.

   a. Comparison of grazing capacity.
   b. Comparison of vegetative composition.

      1. Perennial grasses.
      2. Annual "   .
      3. Good perennial weeds.

4. Poor perennial and annual weeds.
5. Sagebrush.
6. Shrubs other than sagebrush.

MAJOR PLOTS

Craddock: The major plot method of range cover analysis is one refinement of the grazing survey, or estimate method principle, which has been developed to study in great detail plant associations on limited areas. These plots differ from grazing surveys chiefly in that instead of making observations over a given type as a whole the estimates are concentrated on a definitely established area which is selected as being representative of a site.

The sample, or major plot, is adaptable to a number of special studies. If the plot is representative of a given area a reconnaissance estimate of the vegetation on the plot will yield an average inventory of the plants on the whole type. If a complete inventory is not desired the number or crown density of one or two species only may be recorded. This scheme is particularly useful in successional studies of invading plants. The plots also can be designated as sites for phenological measurements in connection with staked plants or the areas can be used as stations for judging degree of utilization by actual seed stalk counts before and after grazing.

The size and shape of the major plots may vary according to the type of vegetation or the nature of the problem being studied. In the Intermountain Region, however, the major plots are usually one rod square and each is divided to facilitate study, into quarters or strips.

Transect-Sample Plots. - The transect-sample plot scheme is another refinement of the grazing survey estimate method. This scheme has been the usual method followed in timber cruising work but to date has not been used very extensively in grazing studies. The principle embraces a number of advantages however and for detailed range studies on limited areas it seems particularly adaptable.

As employed in range studies the transect-sample plot method is not very different from the principle involved in timber cruises except that the plots are usually smaller and are located at more frequent intervals. For example: In a study of sagebrush range in southern Idaho 100 stations were mechanically located one chain apart in a 10 acre enclosure. These stations served as accurate control for a detailed type map. After the acreage of each type had been determined by planimetering it was found that the sample plot stations occurred on respective types almost proportionately to their acreages. In this instance it was very simple to move three of the stations a few feet to such type sites as seemed necessary to coordinate the occurrence of the type stations with their respective acreages. The size and shape of the plots which were found to be most convenient for this study were circular and six feet in diameter. The manner of studying the plots was simple. A wire hoop, six feet in diameter was centered and dropped over each of the permanent stations and the density of the vegetation within the circles was then estimated, recorded by types, and a final weighted average density for each species determined.

The transect-sample plot method as just described is useful in securing a detailed inventory of the vegetation. The mechanics and technique may be altered to satisfy the peculiarities of a variety of conditions but the principle seems sound and in practice the method is easy to apply. The scheme differs from a grazing survey or the major plot analysis in that instead of securing but one estimate a number are made at regular intervals over each type. These replications serve to accentuate the mean, and, also, to indicate the range or variation within the types. The number of replications which are needed definitely to establish the identity of the various types can quickly be determined through a statistical analysis of the data. In addition to more definitely establishing the characteristics of a given type the replications also serve as a check upon the accuracy of the estimates.

Belt Transects. - The belt transect is a fourth modification of the estimate method group. In reality it is an elongated sample plot the dimensions of which may vary as widely as may be necessary to include the peculiarities of a given plant association. The transect may be long enough to cross a ravine from ridge to ridge or it may be established on one aspect only, depending upon the nature of the information desired. The vegetation may be mapped and plotted individually or the density may be determined on segments and finally compiled to yield an average value. The former technique is usually employed in timber and brush studies whereas the density estimates are probably more convenient in herbaceous stands.

FREQUENCY STUDIES

W. G. McGinnies: The principle involved in the frequency of occurrence of species long has been the basis of studying plant populations by botanists and ecologists. These frequency studies usually have been applied to plots of varying sizes and shapes simply by recording for each sample the number or occurrence of each species. In some instances the sample plots have been no more than a meandering line across a plant association along which the species are listed sequentially. More common have been rectangular or circular plots, or continuous belts of varying width. In either case, however, the schemes have required only the listing of species, irrespective of size, shape, or form.

These methods, when applied to range investigations, are useful in quickly ascertaining the relative composition of types. Much time is required at the outset to lay out the plots but subsequent measurements may be made rapidly. The data obtained usually is voluminous but has the advantage of being amenable to a statistical analysis and therefore useful for an added research method. There is one important criticism of this type of method, however. The data fails to show the vegetation in terms of ground cover and in studies of watersheds and forage types the density of the vegetation, of course, is highly important.

Raunkaier's method of studying frequency has been employed by two variations, on studies in the Covillea desert type on ten different areas. The new plots on the Santa Rita Experimental Range are 2-1/2 acres in size. Each plot is divided into four sections containing 5 quadrats.

These quadrats are mapped by the use of an alidade. 100 frequency tests are taken on each plot. These are made by using a frame one foot square, which is dropped on the ground at intervals of five steps and the species inside the frame are counted. It is difficult to find out what size sample plot to use. We are now using meter-square and tenth meter square quadrats. The probable error is less on meter-square quadrats than on those of one tenth square meter. This method eliminates the ocular density estimate error. We make 200 examinations of sample plots per day. This number is actually 400, because 200 meter, and 200 tenth-meter sample plots are included. These examinations are run twice to determine variations during the season. The meter-square sample plot fits Raunkaier's curve better than the tenth-meter. On over-grazed areas or on burns fewer species are found. In studying abundant species the ratio between the tenth-meter and the meter sample plot is one to one. The ratio of species occurring in small numbers is 1 to 4.

Methods Used in a Study of Response of Lower Vegetation to Removal of Competition with Trees in Western Yellow Pine in Central Idaho

Floyd Otter

Purpose of Study: To find out what is the natural response of vegetation when trees are removed. Studies will be made under undisturbed conditions; when a tree is killed by lightning; when trees are removed by logging.

The study is preliminary to more work to be done in an attempt to determine the relation of the vegetative cover to securing natural reproduction after logging.

This summer's work has been a one-year preliminary study, one main object of which was to develop methods. Obviously the final result must await studies on the same areas covering several years.

Methods:

1. Comparison of live and dead trees.

a. Selection of one live and one dead tree where slope, exposure, soil, size and age of trees, and all other factors are as nearly identical as possible.

b. Run transects out from each tree in four directions taking meter square plots at every odd meter. Every species is listed. These transects are run to a point far enough from the trees so that the vegetation seems to be free from influence of the tree.

2. Comparison of forested and open areas.

Line transects were run from nearest Yellow Pine trees available into the open, attempting to get comparable conditions and taking soil samples and photometer readings. Species on every odd meter were listed and described briefly according to attached plot description form.

3. Photographs can be used to excellent advantage.

4. Some reproduction plots established in 1914 were remeasured and a check made on the species of plants present.

METHODS OF STUDYING FORAGE YIELD
WITH SPECIAL REFERENCE TO CLIPPING STUDIES.

Matt J. Culley - Chairman.

In any study of range management, whether it be for the purpose of watershed protection, prevention of erosion or the raising of livestock, etc., some measure of the amount of vegetation present must be secured. Under the first two conditions mentioned above density measurements of the stand of vegetation may suffice at the outset, tho' ultimately total volume of vegetation must be measured in order to have a proper basis of study. Range management in connection with the raising of livestock is primarily concerned with the total volume, of vegetation palatable to stock, that is produced. In the main this has, for administrative purposes, been expressed in forage acres which in turn are based solely on density and palatability estimates without provision for measuring actual volume in definite terms. The use that has been made of forage acres, in expressing range capacity, amply justifies their existence; however, research requires a more definite quantitative measure that will permit of direct comparison one year with another, as well as between different areas in the same year, in an effort to solve the relative influence of the many factors that effect vegetative growth. On the Santa Rita density measurements supplemented by height growth measurements have long been used as a means of indicating volume production. In later years this has been supplemented with flower stalk and basal leaf counts. The resulting data, while giving a fair basis of relative yields over a period of years and permitting a reasonably good analysis of the part played by various factors in their influence upon plant growth, lacks expression in definite quantitative values that can be used for direct comparison.

In order to arrive at a more definite measure of yearly production by various grasses artificial clipping and weighing of grasses has been tried and gives promise of yielding results that are much more exact and at the same time readily usable for studying various influences upon plant development with an ultimate possibility of being serviceable in determining range capacity. Clipping and weighing when supplemented with actual measurements of density permits of expressing production in a definite weight per unit of area and thus makes possible a direct comparison between years and between different areas in the same year and also between various species of grass. Artificial clipping studies undoubtedly have their limitations at the present stage of development; however, with the perfection of technique there is every reason to hope that they will yield much more satisfactory results than our present methods.

Various questions were raised in connection with clipping studies, such as: difficulty of simulating actual grazing conditions, lack of litter being returned to the soil, accelerated erosion around clumps, invasion of plants from outside onto the clipped areas, lack of seeding, possible ill effect of continued clipping on plant vigor, lack of trampling effect by stock, and possibly others. There seems little reason why most and possibly all of these apparent obstacles cannot be overcome with proper concentration on technique. Even at the present time there are certain

phases of volume yield studies that are not affected by any of the above difficulties, at least to any appreciable extent.

Arrayed against the objections are some advantages that, with perfected technique, cannot be overlooked: i.e., clipping work offers a degree of control that cannot be duplicated under actual grazing conditions without considerable expense and also gives definite measures of production that cannot be secured under actual grazing. Any desired intensity or frequency of use can be maintained as long as desired, a factor that should mean the securing of results, on any certain system of use, in a minimum length of time. The elimination of the rodent factor is also more easily accomplished at a minimum of cost. Variations in such factors as rainfall and soil conditions can be eliminated more easily.

There seemed a general concensus of opinion at the meeting that there is a real need for better methods of determining forage yield. On the chance that artificial clipping might offer a solution the general trend of comments on future clipping studies was toward concentration on technique in clipping methods. Chapline suggested study of other possible methods for determining volume production. Sampson suggests laboratory methods in perfecting technique and then carrying work into field. Cooperrider suggested the use of an instrument like a husking peg as an aid to technique in simulating grazing by stock. Canfield feels actual grazing may be simulated more closely by clipping only a part of grass clumps at specified intervals, Sampson has already noted retarded root growth under clipping and Forsling suggested the possibility of studying root development under varying clipping methods as an aid in determination of the various influences. Foogler suggested the use of paired quadrats that might be clipped in alternate years as a means or reducing the danger of rapid deterioration often encountered in successive years of clipping. Shoemaker believed clipping work was an aid to administration in establishing opening date for grazing as well as an effective demonstration to stockmen. Ware was inclined to discount many of the objections raised against artificial clipping and felt that, even now, such work was giving results that did not differ greatly from what would be secured under grazing controlled to the extent that clipping work is. Culley described the use of nails with different colored heads, to designate different species, set in the ground to the desired clipping height. Canfield has devised a gauge that fits a large pair of shears that can be set so that the vegetation can be clipped to any height from one to four inches.

Some possible phases of range research, in which clipping studies may prove of value are: determination of seasonal production of different species of vegetation, determination of variation in production between years and between different areas in the same year, relative production of various species, variation in production under any desired system or degree of use as simulated by clipping, determination of chemical analyses and feed value of various species at all seasons of the year and under varying conditions of growth, determination of moisture requirements of different grasses, as well as the same grasses, under varying methods of treatment, determination of influence of volume upon runoff and quite probably other phases that are not yet apparent.

From the above comments, as well as the general discussions at the meeting, there should be sufficient incentive for range research workers to think seriously along such lines and thus add their bit to the improvement of methods now employed.

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METHODS OF STUDYING PLANT DEVELOPMENT AND LIFE HISTORIES

R. J. Becraft, Chairman

E. W. Nelson outlined the methods in use at the Great Basin Branch of the Intermountain Station. He indicated that these are a further development of the methods discussed by Sampson and Malmsten in Department Bulletin 1405, "Grazing Periods and Forage Production on the National Forests." Five plants of each species are tagged in series representing main forage types and elevations representing about 15 different conditions. Starting with the date that snow goes off, the growth and development of the plants is checked and recorded on a form, first at 5-day intervals, then at 10-day intervals throughout the main summer period, and again at 5-day intervals toward the close of the season. These records are checked closely against all the information taken on climate at 3 climatic stations, one in the oak-brush type, one in the aspen type, and one in the spruce-fir type or alpine zone. In addition to the temperature, rainfall and other climatic records, soil moisture records are taken in these 3 types or zones for correlation with the growth records. Three samples are taken at each place and at each of the 3 depths at which the soil moisture is taken, 1 to 6 inches, 6-12, and 12 to 18.

Sampson brought out that the difference in growth of grasses, weeds, and browse is so distinctive that it is necessary to have an outline for each class. He explained that the numerical scheme for indicating development of plants as discussed in Bulletin 1405 has been tried out further in California to good advantage. It makes possible good comparison of one zone to another, especially in correlating dates of different stages of growth of plants in different zones.

Shoemaker: Proper season of use is a primary fundamental on national forest ranges. The administrative organization has accordingly developed the method of studying plant development by different grazing zones. A form is used on which is recorded all the essential factors affecting the site where the records are taken and which is permanently marked so that one can return to the spot and make similar records at intervals. Thus the gradual development of the important forage plants on the range in each of the main types is recorded periodically with a view to determining such essential management features as average dates when the range is ready to graze, dates when seed has developed sufficiently to permit grazing on those areas handled under deferred grazing, etc. The work has clearly indicated that the important forage plants on the range should be the basis for judging range readiness rather than attempting to determine this from plants that might be considered as indicators of range readiness, unless these indicator plants are the more important forage plants on the range.

Chapline: Arnold Standing is making a statistical analysis, with the Hollerith machine, of the plant development records collected by administrative officers in the Intermountain Region of the Forest Service. We hope to have this followed by similar analyses in all regions and have suggested a standard form for coding the records in order to facilitate analysis for all species throughout the West. Our research personnel are

able to study only a few species, and these in localized areas. The analysis of data collected by administrative officers for many latitudes, elevations and other features for the same species and for many species not worked on by research will supplement the intensive studies and greatly add to their application value.

The late Douglas Ingram found on the Ochoco Forest in Oregon that overgrazed range was 6 weeks later in reaching vegetative readiness than range protected from grazing. It was slightly later in starting and much slower in development. This fact has considerable influence on the study and analysis of much of the plant development data and upon application of findings, since it clearly indicates that it is advisable to have the plant development plots representative of the average conditions on the range under consideration. It also indicates that if records are taken on an overgrazed range they can not be effectively applied on a range similar in elevation and other factors but which is not overgrazed.

Seeding Habits of Range Plants

Miss Sylvia Griswold outlined her studies of seeding habits of range plants in central Utah. These cover intensive study of 12 grasses, 10 shrubs, and 30 weeds. An effort is being made to study the relation of production, germination, and survival of seedlings to factors of habitat, especially intensive utilization by livestock and other factors affecting life history. The seeds were stored in paper containers at room temperatures. Seed germination was tested both on petrie dishes and in soil. Tests were made at various temperatures, under both wet and dry conditions, under light and dark, and under natural conditions occurring at Chicago, where the tests were made. Tests range from 18 to 383 days, some seeds failed to germinate the first year so that it was necessary to continue the tests for over a year.

METHODS OF STUDYING UTILIZATION AND PALATABILITY

D. A. Shoemaker, Chairman

Shoemaker: Palatability and utilization are inseparable. The palatability of a plant is defined as the extent to which the annual growth of that species is taken when the range as a whole is properly utilized. Proper utilization may be defined as the way the range should look at the end of the grazing season. It is seen, therefore, that the palatability of a plant must be determined before we have a basis of proper utilization. The palatability of a plant is dependent upon two things: first, the likeness that stock have for it; and second, the extent to which it may be grazed without injury to the plant.

In judging utilization, we must differentiate between range utilization and range condition. They are not the same. As an example illustrating the point, a range unit may be in a seriously depleted condition from overgrazing and at the same time may not have had any grazing animals on it during the current season. It is in an overgrazed condition but it could not be said that it is over-utilized.

Palatability must be based upon individual forage species. Likewise, utilization must be based upon the important forage species rather than upon the general aspect of the range. In other words, the examiner must analyze the range in determining its utilization. Also, allowance must be made for the annual variation in forage production and the standard of utilization based, as far as possible, upon the production during average years.

In actual practice, in judging utilization of ranges, we must first determine what would be desirable use and then decide what must be accepted as satisfactory. Under actual grazing conditions, some parts of the range may be over-utilized under the best of management by the time the forage, as a whole, is properly utilized. It has been determined that generally throughout the Southwest we must accept from 3% to 5% of the area of the ranges in an over-utilized condition in order to get proper use of the range as a whole. Likewise, we may have to accept the over-utilization of certain species which may be of high palatability but constituting only a small part of the forage.

The general methods and factors used in judging or measuring utilization are as follows:

Grasses:

(1) The average height of the foliage ungrazed as compared to the height after grazing.
(2) The percentage of seed stalks left.
(3) The percent of volume remaining.

Browse:

(1) The percentage of the number of ungrazed shoots that are left after grazing.
(2) The total length of ungrazed shoot growth as compared to the length after grazing.
(3) Planetable mapping of browse species before and after grazing.
(4) Tagged individual plants or branches of plants with records on them.

Weeds:

Percent of volume of leafage remaining after grazing.

The following formula is one method of determining "type" utilization:

Important forage species	Average height of plant or length of stalk or stem in average year	Height or amount of plant left on the range: Proper		Height or amount of plant left on the range: Current Year		% of total forage which plant represents	Percent of Total Forage Left On The Range: (4) x (7)	(6) x (7)
		Inches	% of total growth of plant	Inches	% of total growth of plant		Proper	Current Year
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Arizona Fescue	14"	10"	70	12"	86	25	17.5	21.5
Mountain Muhlenbergia	18"	9"	50	10"	55	30	15.0	17.5
Red and Yellow Pea	14"	3"	20	6"	36	15	3.0	5.4
Yarrow	-	-	80	-	50	5	4.0	2.5
Fendler's Ceanothus	6"	3"	50	4"	66	10	5.0	6.6
					Total		44.5%	53.5%

% under or (above) is 53.5% minus 44.5% equals 9% under.
% present year's forage crop is below (or above) average - equals 10% below.

In using the formula, it is intended that all of the headings and the data for all columns excepting numbers (5), (6), and (9) would be prepared by a member of the Supervisor's staff in cooperation with the ranger for each important forage type on the ranger district. The data for column (2), as the heading indicates, should represent the average size of the plant under average growth conditions for that particular type and locality. The current season variation in forage growth should be stated in the footnote as indicated. The per cent figure in column (4) is the difference between 100% and the per cent palatability of the plant, i.e., it should be the per cent of the current year's growth of the plants that should be left on the ground.

With the form properly prepared, all that the person using it in the field would have to determine would be the average height or the amount of the current year's growth of each species that is on the ground at the time of inspection - preferably near the close of the grazing period and enter this figure in column (5). The figures for columns (6) and (9) are determined by simple computations after column (5) is filled in.

Another method used to advantage, especially on sheep ranges, is that of laying out and recording small plots just before grazing and then recording them after the sheep have grazed over them. Often the two records may be made the same day.

Panel exclosures which may be put up each year are valuable in showing the season's growth as a basis of judging utilization of the surrounding range. Panel exclosures so used are more valuable than permanent exclosures since the latter may not reflect the present condition of the surrounding range. The vigor of the plants is apt to be different causing a greater forage production in the exclosure and, in the older plots, there may be a considerable change in composition.

Methods of determining utilization involve also: (1) observation by intensive inspection; (2) the reconnaissance method which compares the amount of utilization with the type palatability; and (3) the condition of grazing animals.

Forsling: The study of utilization of forage species for the maximum degree of grazing which may be practiced without injury to the vigor or productivity of the forage plants is one of the more difficult problems met with in research. Considerable thought and effort has been devoted to this phase of range management in both the administrative and research organizations. Good progress has been made and the rules of thumb which have been developed have proven useful and valuable. They are rather deficient, however, because the methods so far developed are based upon estimate rather than accurate measurement or thorough analysis. It is true that the estimates have been as consistent as is possible but there is a need for replacing them by more specific measurements.

The problem segregates itself into two phases: 1. How closely can a species be grazed under a given condition without detriment to that species; 2. A method should be developed to determine this degree of grazing by actual quantitative measurement, at least for use as a basis for checking ocular estimate, that is sufficiently standardized so that the system can be conveyed from one individual to another without distortion of what constitutes a given degree of grazing.

Thus far the Intermountain Station has been approaching the first part of the problem by the enclosure and exclosure method and applying different degrees of utilization to small panel exclosures over a period of years and then measuring the influence of a given degree of grazing by the reaction of the vegetation as shown by quadrat studies. This method is now considered to be too empirical. The clipping method also has been used but has severe limitation because of the difference there

is between clipping the plot and the manner in which animals would actually graze it. Perhaps a study of physiological and chemical response by chemical analysis of specimens which have been subjected to various degrees of use under actual grazing offers a means of more accurately measuring the influence of utilization. Perhaps a combination of the three methods will be necessary for a final solution of the problem.

With regard to the measuring stick of utilization, the following method which has been developed at the Intermountain Station has proven useful in checking ocular estimates. Temporary or permanent quadrats are selected at random. The actual number of individual plants or tufts of grass are first counted and the number of specimens by species which have been grazed are then recorded from which the percentage of the number of specimens of each species which have been grazed is determined. An estimate, checked by measurement and flower stalk counts, of the percentage utilization of the grazed specimens by species, is then recorded. The product of the per cent of plants grazed and the per cent of grazed plants taken gives the per cent of utilization for the individual quadrat. This method is very practical for use in "checking the eye" in making ocular estimates. It often reveals some striking differences in utilization as compared to making ocular estimates without a detailed check.

Chapline: In studying utilization and palatability of goat ranges, relative values of the different species were determined both by establishing a plot ahead of where the goats were going to graze and checking it carefully, and then examining it after the goats had passed over it. In addition I would allow the goats to graze around me, and with field glasses check as carefully as possible just what they were taking. Such records were made of utilization throughout the period of use of each part of the range. Relative palatabilities were determined by studying average degree of grazing of each species when the range as a whole was properly grazed. This was determined largely by checking the ability of blue and side-oats gramas to maintain their vigor and density on quadrats representative of the more important types, which were grazed to different degrees. In the goat range work, the records of grazing of individual species were kept in a notebook. This has been systematized until at present in Forest Service work a form has been developed for systematic records of these data. On page 8 of Department Circular No. 62, "The Utilization of Browse Forage as Summer Range for Cattle in Southwestern Utah" a summarization of such data is given.

In answer to Dr. Sampson's question: Correct utilization of goat range depends mainly upon the proper degree of grazing of the grasses, when the range is grazed during the summer or where the grasses make up a small part of the stand. On winter range where the grasses make up a considerable part of the stand, the proper utilization of the more palatable browse species will usually form the basis for proper utilization of the range, because with winter use only an abundant stand of grasses is seldom injured when the browse is properly grazed.

Measuring Utilization and Palatability on The Jornada Experimental Range

By

R. S. Campbell

During the sixteen years study of natural revegetation and grazing capacity on the Jornada Experimental Range in southern New Mexico, the utilization which can be allowed of the principal forage species has been pretty well established. Intensive study of the maintenance and reproduction of black grama (Bouteloua eriopoda) has shown that it can be used during the fall, winter or spring each year to within two inches of the soil surface, and still make satisfactory growth the following summer. Since the average height growth of black grama on the Jornada is about 10 inches, it is assigned a palatability or full use figure of 80 per cent. Associated species are given palatability percentages corresponding to the average amount eaten when black grama is grazed fully. Thus the utilization estimates for fall, winter and spring ranges are based entirely on the use made of black grama, where that species is either actually or potentially dominant, because it is the most important feed-producing species on the Jornada.

On summer ranges, the utilization estimates are based upon the use made of tobosa grass (Hilaria mutica) which is considered 60 per cent palatable.

On account of the large pastures on the Jornada range, varying from 1,800 to 84,000 acres, the utilization estimates each quarter must be made upon a fairly extensive basis. The method used is based upon extensive range reconnaissance practice. From ocular observations, records are made by types, with separate writeups for different compositions and for different degrees of utilization within the same vegetative type. The writeups include estimates of reconnaissance density, composition, and percentage of herbage grazed for each species. When areas upon which there are meter quadrats are inspected, writeups are made both for the quadrat proper, and for the surrounding area. The observation of these small plots serves as a valuable intensive check for the more extensive estimates made on larger areas.

In compiling the utilization figures, each type writeup is completed as in extensive reconnaissance, and the type boundaries are drawn in on a map of sufficient size to planimeter easily. The following data are tabulated for each type: number, area (by planimeter), forage acre factor, forage acres, percentage type makes up of total forage acres in the pasture, average utilization, and weighted utilization factor. A sample tabulation for a pasture follows:

Type No.	Area Acres	Forage acre factor	Forage acres No.	Proportion of total forage acres Per cent	Utilization Per cent	Utilization factor
1	500	0.100	50.0	25.0	75	18.8
2	1,000	.075	75.0	37.5	50	18.8
3	500	.150	75.0	37.5	25	9.4
Totals	2,000		200.0	100.0		47.0

Based on the palatability percentages of the principal forage species, this sample pasture has a utilization of 47 per cent of full or proper use.

The utilization percentages for each pasture are applied directly to the actual record of stocking in determining grazing capacity. If the sample pasture shown had been grazed 47 per cent of full use by 50 head of cattle, figured on a yearlong basis, then 106 head yearlong would have grazed it 100 per cent. Under southern New Mexico climatic conditions, allowing 25 per cent of the yearlong grazing capacity of the pasture as a margin of safety in case of drought, the sustained yearlong grazing capacity would be 80 head of cattle. This figure would be used in the development of management plans for the pasture.

Sampson: 1. In the study of the food habits of deer binoculars were used to note the species of plants eaten and the particular part of the plant taken. Immediately after the deer had left a plant that specimen was collected and made a permanent herbarium specimen and filed in the deer utilization pigeonhole. In important instances photographs were taken of these specimens to show the parts consumed and the degree of utilization.

2. Stockmen in California very generally claim that browse grown on burned areas is appreciably more palatable than that produced on areas which have not been burned for several years, or not at all. Preliminary chemical analyses indicate that shrubby vegetation produced on recently burned lands contains a higher percentage of mineral constituents than that grown on unburned areas. Orr, J. B., in his book "Minerals in Pastures", published by H. K. Lewis & Co., London, 1929, holds firmly to the belief that the mineral constituents of forage determine not only its palatability but is the biggest factor in determining nutritive qualities. He points out that the percentage of mineral constituents bears no relation to the protein content or the carbohydrates. This problem will be investigated in detail.

3. The proper utilization of a mixed chaparral, grass and weed range, even though the former predominates, may be determined by the extent of grazing of the herbaceous cover. Certainly on many ranges it is possible to work out a correlation of use for a given class of stock between the herbaceous and the woody growth. In general it is desirable to base the utilization on the density and luxuriance of growth of the herbaceous undercover. The proposed correlation justified careful study of the browse cover in relation to the utilization of the herbaceous type.

Range Utilization at the U. S. Sheep Experiment Station

By
George W. Craddock

Estimates of forage utilization are made on the range of the U. S. Sheep Experiment Station in southeastern Idaho both intensively and extensively. The methods used in either case are essentially the same except for the difference in the amount and detail of information obtained and the difference in the size on the units used as bases for compilation.

The range of the Sheep Station is a solid sage formation in which there is an understory of bunch grasses and weeds. The grasses furnish the bulk of the feed on the range and Agropyron spicatum, because of its abundance, is considered the key species in respect to forage value of the type. The range is lacking in topographic relief and except on small areas it is difficult to break the main formation into subtypes. For these reasons, estimates of utilization on the herded range are made extensively, using sections as units of control and the single species, A. Spicatum, as an indicator of the degree of use.

Estimates are obtained extensively by traveling twice through each section and noting the average utilization of the wheat grass. If other forage species are abundant locally they are included along with the wheat grass estimates but no attempt is made to weight the values by volume. The degree of utilization derived for each of the sections are added and the average for the entire range computed. On the herded range normal use has been found to approximate 60 per cent.

A more detailed estimate of utilization is obtained on the experimental paddocks. The sage formation is broken into subtypes in each of which are found distinct associations of species which can readily be weighted volumetrically by reconnaissance. The degree of utilization of the principal species in each of these types is made and the average for each pasture computed from these weighted values. Utilization of all available forage in the experimental pastures usually exceeds 95 per cent.

The estimates obtained extensively on the herded range and the more intensive estimates on the fenced areas rather closely agree with actual per acre carrying capacity records. The fenced range has been found to carry consistently nearly twice as many sheep as can be grazed on the same type of range under a herding system.

O. J. Murie: In the study of food habits of big game I have used two methods: analysis of stomach contents and direct observation. Neither of these methods is satisfactory by itself, but each should be used as a check on the other. In the study of Alaskan caribou some items, very palatable, did not appear in stomach analysis. On the other hand, field observations did not reveal the high percentage of grass utilized. Grasses were eaten very extensively but lichens were very important and very palatable.

In the case of the elk it proved difficult to note the utilization of grasses by examining the range since elk are dainty feeders. Stomach examination revealed the fact that a high percentage of grass was being used. By the observation method one is able to learn what species are avoided as well as what species are palatable. For example, a caribou was seen to consume willow buds, avoiding alder buds nearby. Elk were fond of one species of Senecio but avoided another similar species nearby.

The method used in observation consisted of finding an area recently grazed by a band of elk. Note the composition of a convenient area, listing plant species and noting approximate density. Then list plants used with percentage of utilization of each as nearly as can be judged.

Large numbers of stomach samples should be collected, distributed throughout the year.

In the case of field observation, a large number of instances should be averaged.

Chemical analyses of food plants and mineral licks have been made.

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Summary

Palatability:

The palatability of a plant is the extent to which its annual growth is taken when the range as a whole is properly utilized.

The methods of determining palatability are:

(1) Determine the resistance to grazing of individual species
  (a) By clipping studies.
  (b) By different degrees of controlled grazing by animals.

(2) Determine the extent to which plants are grazed during different seasons of the year
  (a) By field observation of grazed range.
  (b) By study of sample plots on grazed range.
  (c) By observation of animals actually grazing.
  (d) By stomach content analysis which may include collection of plants to aid in identification of material.

(3) Chemical analyses of plants to correlate with observations.

Utilization:

Proper utilization may be defined as the way the range should look at the end of the grazing season. It must not be confused with range condition.

The methods of determining range utilization are:

(1) Observation by intensive inspection.
(2) Reconnaissance method, comparing utilization in per cent with type palatability.
(3) Condition of livestock as a supplemented check.
(4) Observation and record of the amount taken of the most valuable forage species which may be a single species.
(5) Formula presented in the Southwestern Region's Range Management Handbook, Page 134.
(6) Sample plot records, particularly on sheep ranges, by following bands, laying out plots and recording them just before sheep grazing and taking records again soon after grazing.

(7) Direct observation of grazing animals by use of field glasses.
(8) Sample plot records by periodic examination.
(9) Counting numbers of grazed and ungrazed plants on a sample plot and the per cent that each is grazed.
(10) Use of permanent or temporary exclosures to determine current season's growth for comparison with grazed ranges. Temporary or panel plots are preferable.
(11) Observation and records of quadrats.
(12) Frequency method with estimates or measurements of utilization at each station.

THE USE OF EXCLOSURES AND ENCLOSURES IN CONTROLLING THE GRAZING FACTOR

Arthur W. Sampson, Chairman

It is well known that growth and reproduction of higher plants are interrupted or greatly curtailed by frequent or very close grazing. Grasses and similar plant forms, with basal meristem in the leaves and with shoot buds near the ground, are less subject to injury by grazing than are broadleaved herbs and shrubs, the leaf expansion of which takes place more or less over the entire leaf area.

In order to study carefully the grazing coactions upon different types of pasture vegetation it is helpful to control the grazing factor. This may best be done through the use of two distinct types of plots, namely, the exclosure and the enclosure.

Definition

The term "exclosure" in its stricter usage implies the employment of plots to exclude from within the larger herbivora, and in the more refined work, the rodents as well, by fencing against them. Exclosures vary greatly in size and may include several acres.

"Enclosure", as the term implies, is a fenced plot, usually of definite size, constructed to retain within its borders a desired number of domestic or game animals, a selected number of rodents, or the normal population occupying the area at the time of establishment. Enclosure plots also vary greatly in size, varying from a part of an acre to a section or more of land.

Uses of Exclosures and Enclosures

Exclosure and enclosure plots are effectively used in the study of a great variety of range and pasture problems. Some of their most common uses may be enumerated under two main heads, namely, (1) the vegetation itself, including its maintenance under varying degrees of pasture use, and (2) the foraging animals, both domestic and native, in their reaction to the different forage and browse associations.

The vegetation studies generally are concerned with the regeneration of the more desirable species, hence with the rate of plant succession under various systems of pasture use, as compared on the one hand with the successional activities under total protection from foraging animals, and on the other hand with continuous season-long grazing. Some of the more valuable records procured have shown the time required for thorough revegetation by some form of application of deferred and rotation grazing of the different forage types. Incidentally exclosures furnish information as to the species that constitute the climax and subclimax vegetation; the effectiveness of the different species in controlling erosion and in building up a soil horizon capable of absorbing and retaining abundant precipitation; the proper time for opening and closing the grazing season; the gathering of phenological observations unhampered by biotic influences; the normal

establishment of reproduction of timber species and their rate of growth as compared with that on annually grazed range; and many other important points.

In animal studies the application of exclosures and enclosures are equally extensive. In the case of domestic livestock they are specifically concerned with the movements of the animals in the gathering of their food; the choice of plants at different seasons and the particular parts consumed; the merits of different grazing systems; and probably most important, the grazing capacity of the different range types and the amount of salt and water utilized while grazing thereon. In the study of the larger game animals, such as deer and elk, exclosures and enclosures serve to indicate such important points as the proper sex ratio, the age when they first breed, the normal mating season, and the natural rate of increase. In the study of rodents, the food habits, amount of forage consumed, breeding characteristics, and rate of increase are effectively studied.

Craddock states that at the Sheep Experiment Station a number of enclosures have been used to determine the influence that various periods of sheep grazing may exert upon the native vegetation. Nine such pastures have made it possible to study the influence of a wide variety of grazing schedules. The extreme schedules are: (1) complete protection from grazing in the spring but with complete use in late fall; (2) continuous utilization during the spring period from two weeks after the inception of growth, and again complete use in the late fall. Between these extremes other schedules have been employed, particularly with reference to deferred and un-deferred schemes of management.

Forsling: Exclosures supporting the natural climax vegetation are of inestimable value for reference and comparison in range research, not only the vegetation, but of the soil and other factors. Suitable areas usually are difficult to find because of the thoroughness with which livestock have grazed almost every accessible piece of land available. Frequently careful search of cemeteries, unused corners in dry land farming areas, etc., will disclose valuable areas of climax vegetation which may be used to advantage. In other instances it will be necessary to select areas on grazed range in the best state of preservation that can be found, which, if fenced, will be restored to climax after a number of years. It would be well worth the effort to locate and preserve small areas of climax vegetation in every important type or community in the range area.

Working on the Santa Rita Range Reserve, Culley states that they have two main purposes for their exclosures: (1) exclosures erected for intensive study of the change that takes place in both the density and volume growth of the principal range grasses, and (2) exclosures erected very largely for general observations on the growth of the principal grasses from year to year.

In the United States the U. S. Forest Service, the Biological Survey, State Experiment Stations, the Carnegie Institution, and certain other agencies have made extensive use of exclosures and enclosures. Some of the more important results that have appeared in American literature are:

Forsling, C. L.
1931 A study of the influence of herbaceous plant cover on surface run-off and soil erosion in relation to grazing in the Wasatch Plateau of Utah. U. S. Dept. Agr., Tech. Bul. 220.

Hanson, H. C.
1929 Intensity of grazing in relation to proximity, and in relation to isolation transects. Ecology 10:343-346.

Hanson, H. C., D. L. Love, and M. S. Morris.
1931 Effects of different systems of grazing by cattle upon a western wheat grass type of range. Colo. Agr. Exp. Sta. Bul. 377.

Sarvis, J. T.
1923 Effects of different systems and intensities of grazing upon the native vegetation at the Northern Great Plains Field Station. U. S. Dept. Agr., Bul. 1170.

Taylor, W. P., and J. V. G. Loftfield.
1924 Damage to range grasses by the Zuni prairie dog. U. S. Dept. Agr., Bul. 1227.

Weaver, J. E., and F. C. Clements.
1929 Plant ecology. McGraw-Hill Book Company, Inc. New York.

Size of Plots

The size of exclosures and enclosures to be established must be determined by the character of the vegetation, the climatic conditions, the species of rodents, and their population. In general inthe Northwest and the Inland Empire, smaller plots may be employed more effectively than in the arid region of southern California and the Southwest where the vegetation is correspondingly sparser. It is desirable to have the plots as large as is economically possible, but the matter of size should not be emphasized to the extent of discouraging the use of smaller ones where funds are limited. The object of the larger plots is to provide representative soil and vegetative characteristics, and to have sufficient space for the establishment of such quadrats and transects as is required for detailed study. Where vegetation is dense, and especially where sod form occurs, less quadrats are needed within the plots for procuring the necessary detailed information than where the vegetation is very sparse and the soil as a consequence is subject to sheet and gully erosion and to drifting. In central Utah, northern California, and similar areas where precipitation is fairly heavy, four or five quadrats appear ample.

Culley: On the Santa Rita Range not less than ten quadrats a meter square in size appear to give a reliable cross section of the vegetative activities on such plots. Obviously these should not be unduly crowded together, and it takes a full acre to satisfactorily establish 10 quadrats.

As a matter of fact, most of the Santa Rita plots are very much less than an acre, with from one to four quadrats established in each. However, the analyses of results from these have indicated the need for a considerably greater number of quadrats in order to get results that indicate definite trends. Possibly our extremely variable climatic conditions coupled with a more or less sparse covering of grass may be somewhat different than is encountered in other regions.

In period studies where actual grazing by stock is employed by means of letting down the fences at certain periods of the year we have found that a two acre plot is about the smallest that can be used effectively. Plots of this size permit the establishment of up to ten quadrats satisfactorily and ordinarily, even in regions of comparatively low density, the effect of trampling along the fences can very largely be eliminated from the quadrats.

In general observation of exclosures we have followed the practice of establishing new divisions at certain points over the Santa Rita Range each year for the specific purpose of observing the current year's growth and, incidentally, by the use of quadrats, to get an idea of the density changes that occur as a result of fencing under the specific climatic conditions that obtained at the time and the cumulative effect of various number of years of protection. Insofar as the current season growth has been concerned these plots have given very satisfactory results. For the most part they are about 25 feet square.

We have, in a great deal of our quadrat work, experienced a certain amount of damage from rodents, which is another reason for larger plots with a greater number of quadrats so that in the event of rodents damaging one or two quadrats we would still have a considerable number from which to draw conclusions.

I do not feel at all that any standard size for exclosures or enclosures can be established since conditions vary so greatly in different regions. Each worker in a locality should know enough about the vegetation and general conditions, as well as influencing factors, to be able to arrive at some conclusion in regard to the size of plot that would give him satisfactory results and by trial over a period of a few years should be able to tell just how effective they are.

Rodent Plots

Dr. W. P. Taylor: In the study of segregating influences of native animals, including rodents and game on forest and range, the use of enclosures and exclosures has proved to be practicable and useful. The enclosure can be utilized to measure the influence of a particular number of a certain rodent or game animal on the soil and vegetation of an area of known size.

The essential conditions of the exclosure method for studying rodent influences on the range are as follows: (1) Fence one area against livestock but freely open to grazing by rodents being studied, (2) fence a contiguous area against both livestock and the rodents in question. Changes in the vegetation under grazing by rodents alone can then be compared with those under grazing by rodents and livestock outside the fences, and with those under protection from both livestock and rodents in the adjoining sample plot.

The game exclosures on the Kaibab Forest, Arizona, are of extraordinary interest and value. There is probably no method superior to this for indicating with some precision exactly what are the ecological effects on the vegetation of an overabundance of deer.

Campbell: Some years ago several rabbit proof exclosures, from 12 to 15 feet square, were constructed on the Jornada Experimental Range. Both the take down panel and the permanent types were installed. Unfortunately, most of these small exclosures filled so deeply with sand (the soil of the region is a loose sand), that they failed to serve fully the purpose for which they were intended. Both the mesh wire of the fences, and the increased vegetation which developed at first, obstructed so much drift sand during the windy spring periods that today sand deposits in some of the plots are as deep as 6 to 8 inches, and the vegetation inside is much less dense than it is outside. The standard cattle exclosure on the Jornada now is one quarter acre in size, and no attempt is made to construct rodent proof exclosures of less than an acre.

The most recent project on the Jornada is a study in the mesquite sand dunes, a type which has large scattered clumps of mesquite, nearly covered by sand, with blowouts in between. The type is regarded as potential grassland, but its present grazing capacity is extremely low. Six hundred forty acres of this type were fenced as a cattle proof exclosure in order to study the vegetative improvement in the type when protected from livestock. The changes in vegetation will be followed by recurrent intensive grazing reconnaissance mappings, supplemented by several major plots and meter quadrats. Rodent exclusion is not planned for this first exclosure, since eventual restoration of the type undoubtedly will have to occur with the rodents present. However, at least one and possibly two additional exclosures of the same size are planned, inside of which rodent proof exclosures of not less than two acres will be constructed in order to study that phase of the problem.

Craddock: The 80 acre plots at the Sheep Experiment Station in Idaho for sheep grazing appear to have been amply large for the purpose of the investigations. The studies aimed primarily at determining changes in vegetation and not in recording changes in body condition or weights of the animals grazed. The latter phases were impossible to follow since the animals used were constantly changed from one paddock to another, or from the paddocks to the herded range.

The response of the vegetation in the pastures to the various periods of grazing has been measured by a combination of quadrats, major plots, transect-sample plots, and reconnaissance surveys. In addition, records have been taken in respect to current fluctuations in growth induced by climate. It has been in this connection that the exclosures have been used.

One rod exclosures have each year been established on typical sites within each experimental pasture. These panel exclosures are each year moved to new sites. The areas so enclosed, therefore, reflect the influence of past years of a particular system of grazing. Phenological measurements taken periodically within these areas have afforded a rather satisfactory

index of the influence which the various intensities of grazing have exerted upon the rate and total development of the important species. It would have been desirable if permanent exclosures had been set up at the start of the experiments, in addition to those which are movable, for such plots would serve as a check on the various grazing schedules over a period of years, whereas the movable plots would show only the annual fluctuations.

The size of the exclosures, whether they be permanent or movable, should be governed largely by the type of vegetation and the nature of the measurements involved. It would seem that minimum requirements suggest qualifications somewhat as follows: that the areas be sufficiently large to include at least ten normal plants of representative species, each of which should be staked, either permanently or temporarily for one year as the case might be, for systematic measurement. The number of plants necessary to yield measurements within reasonable limits of error can be determined only after trial, coupled with statistical analysis. At the Sheep Experiment Station it has been found that on the more severely grazed areas one rod square exclosures are not large enough. The important species have been so depleted on some of these pastures that in order to include ten representative plants of a given species several square rods of range are needed.

Too often grazing experiments have been conducted on areas which have been too small. Limited carrying capacity has thus often necessitated the use of such small numbers of animals that final results probably have been obscured by variations inherent with the animals themselves. Obviously, if but a few animals are used to measure a given factor the influence of that factor would have to be enormous for it to show up significantly over and above the error due to individual variability. Lamb and wool production, as well as gains or losses in body weights of individual animals, are important. Range investigations accordingly can often be made to advantage in conjunction with animal husbandry studies, particularly where it is desired to learn how many pounds of beef, mutton, or wool can be produced from a given acreage of a certain type of range.

Animal husbandry workers and others have come to recognize a variable factor of about 20 per cent and in recent work most investigators are taking this into consideration in planning their tests. At the Sheep Experiment Station fifty sheep are used as a minimum for such studies, and more whenever it is possible to do so. Range investigators should do likewise and when the number of animals has been decided upon they should then, and not until then, decide upon how large an area will be needed to carry the animals over the period of the trial.

Forsling: With regard to size of exclosures, experience has shown that the areas should be large enough so that the exclosure itself does not set up a special condition upon the area segregated. Ordinarily livestock or game exclosures should be not less than an acre in area. This size seems to eliminate undue external influences except under special conditions. The same is true for panel or intermittent exclosures. Rodent exclosures must be somewhat smaller because of expense of construction but should not be less than 50 feet square.

Enclosures are essential for the study of different systems of grazing and should be of a size to accommodate a sufficient number of animals under consideration to reduce the error caused by variation between individuals. The size may be varied with the grazing capacity of the range. For sheep 80-acre paddocks are being used with success at the U. S. Sheep Experiment Station near Dubois, Idaho, and 20-acre paddocks are being used successfully at the Great Basin branch where the carrying capacity is somewhat higher than at the Idaho station.

Sampson: On the foothill ranges of California, where the predominant vegetation is distinctly annual species, exclosures need not be especially larger for reliable results, provided they are fenced rodent-proof. The type changes rapidly following the first three or four years of protection of a formerly fully used range. The cover is unusually uniform as to species, and the ultimate annual type is practically pure. Exclosures of one-fourth of an acre appear satisfactory in the more humid coast counties, but larger plots are recommended on ranges of the interior more arid tracts.

Limitations of Use

A. W. Moore: I have often wondered if exclosures and enclosures present a uniform picture. An interesting picture was presented upon the Snow Mountain district of the Ochoco National Forest in Oregon. A stock exclosure about 20 feet square was placed upon a densely sodded meadow. The soil was of a heavy shot clay type. Columbian and Oregon ground squirrels were plentiful.

Cattle watered nearby and loitered upon this meadow in the vicinity of the exclosure. The soil became packed from trampling although the sod withstood this hard usage. Within the exclosure another picture was presented. The granular clay soil, protected from trampling and aided by natures factors, presented a very friable condition. The ground squirrels took advantage of the exclosure in which it was not necessary to dodge the hoofs of loitering cattle. The sod was gradually removed, crowns and all. Without remained the native sod; within first succession stage weeds.

Another factor is that the rodent exclosures when compared with check areas may present a qualitative as well as quantitative error. Achillea in some parts of the range of the Columbian ground squirrel is taken very sparingly by livestock. However, it is readily taken by Columbian ground squirrels. Lupine and yellow-weed, readily taken by some pocket gophers, present another possible qualitative error.

Taylor: We find that enclosures, especially for rodents, are difficult to maintain, especially if located at a distance from headquarters. If the enclosures are not covered, predatory birds or mammals are likely to capture the experimental animals; or the experimental individuals may succeed in escaping. We have not found the enclosure method so suitable as the exclosure method. The exclosure method has been used to quite an extent abroad in the attempt to isolate animal factors. In England, Watt (Jour. Ecology 11 (1):1-48, 1923), and Tansley and Adamson (Jour. Ecology 13 (2): 177-223, 1925), and in Australia, Matthams (The Rabbit Pest in

Australia, 1921, p. 234-235) have used the exclosure method or refer to results derived from its use.

All exclosures and enclosures are subject to experimental difficulties. Fence effects of various sorts, abnormal habits induced by confinement, incompleteness of control of the factor to be segregated, all must be reckoned with. But probably all artificial experiments are subject to some error, for in each there is some departure from natural conditions. While we are only just now making a beginning in this work, enough progress has already been made to abundantly justify the method.

McGinnies: In using rod-square panel exclosures in Montana it was found that rodent grazing sometimes largely offset the effect of livestock exclusion. For example panels to determine proper opening date were opened at 15-day intervals, but were grazed by ground squirrels from the start. Other exclosures closed at 15-day intervals were grazed by rodents after livestock had been excluded. In several cases the rodent grazing was sufficient to seriously interfere with any possible results of livestock exclusion at the beginning and end of the season. The situation can be remedied in some cases by making the panels rodent proof and in other cases it may be necessary to remove the rodents on special areas. In every case it is very important to know the relative weight of grazing by native and by domestic animals.

The above stated disadvantages in the use of exclosures and enclosures were also recognized by Chapline, and S. B. Locke. They pointed out that too much reliance should not be placed upon exclosures or indeed on enclosures alone in interpreting what is taking place on the open grazed range. Exclosures have considerable value when used in connection with other methods of studying changes in vegetation on grazed range. Instances have been noted where depleted ranges were improving under grazing, but where the ungrazed exclosures improved so much more rapidly than the grazed range that the casual observer assumed that the pastured area was still over-grazed. It is often difficult for those who have not worked extensively with quadrats and other plots to distinguish between close utilization and over-grazing. Moreover, exclosures in some localities, after they have been fenced for a considerable period and attained a heavy stand of vegetation, show a material decline during years of drought, sometimes far in excess of adjacent grazed range. Most of the range research is concerned with the study of principles of range management, and since there are not sufficient funds to provide for the study of all degrees and types of grazing, exclosures and enclosures have been found of value in controlling the degree of grazing, in determining proper season of use, and in studying many other such points. On the Jornada Range exclosures have also been used in studying control of losses of grazing animals from feeding upon poisonous plants at the time they are most poisonous, by excluding grazing until the poisonous plants are not seriously toxic.

Isolation Transects

Exclosures are arranged so that each year a unit in one series can be opened to grazing and one unit in a second series can be closed to grazing, have been effectively used in South Dakota by J. T. Sarvis. In Colorado Hanson reported having secured interesting, but not decisive, data by means of isolation transects like those used by Sarvis. A detailed study over a relatively long period is necessary to procure conclusive results. He feels that the isolation transect may be of value in determining the behavior of particular plant species in response to grazing in different seasons and in different years. Such transects are also useful in determining the importance of various species as indicators of over-grazing, soil depletion, too early grazing, and other such factors.

Mapping the Plots

In regard to mapping exclosures and enclosures, it was suggested: (1) that the plots should embrace a complete small drainage area wherever possible, the drainage system to be sketched in, and (2) that all plots should be mapped as to topography and vegetation.

Culley: In connection with the establishment of exclosures and enclosures during the last few years, we have felt it essential that the entire plot should be mapped in some detail. We are at present using several methods of accomplishing this, such as: (1) where the time is available we are listing the number of specimens of the various species over the entire plot; (2) in the larger protection areas we are attempting to follow Prof. MCGinnies' plan of making a map something on the order of that which is made on intensive reconnaissance, mapping certain areas in which a species is dominant, indicating the location of browse species, and estimating the density of the protection or control area by segments; (3) we are also attempting Prof. McGinnies' adaptation of the frequency index method on the larger plots and if a satisfactory weight index can be worked out I believe the method will prove very satisfactory and will, of course, be much faster than intensive mapping and listing.

This viewpoint is further stressed by Prof. McGinnies, who feels that mapping at the time of establishment cannot be over emphasized. He says: "We cannot turn back the years after the exclosure or enclosure has become important. It is not safe to assume that conditions outside the plot at a later date represent conditions inside the area at the time of establishment. In the first place we are faced with soil and vegetational heterogenuity and in the second place the outside vegetation may have deteriorated since the time the protection plot was established. Furthermore, exclosures will throw a great deal of light on successional stages, especially on the replacement of one particular species in competition with another. Any exclosure is a useful guide, but a little time spent in mapping will increase its value many times. We have a dozen exclosures 10 to 15 years old in Arizona which we would like to trade for one-half or one-third as many with initial maps."

Combination Plots to Study Class Grazing

In some localities combination "exclosure-enclosure" plots have been used for the grazing of a given class of stock, as for example sheep, on a range used in common by sheep, cattle, and horses; and of deer on range grazed by cattle.

In the Southwestern Region, Shoemaker is using effectively these so-called exclosure-enclosure plots so far as cattle are concerned, in connection with the game management studies. Several series of such plots have been established on representative deer ranges. Each plot consists of an area 80' x 80' from which both cattle and game animals are excluded through the use of a combined woven wire and barbed wire fence. A nearby or adjoining area of similar size is fenced against cattle grazing, but is left open to deer. A barbed wire fence is used with four wires of the usual cattle fence construction, with the exception that the bottom wire is placed 20 to 22 inches from the surface of the ground in order to make it easy for the deer to crawl under the fence and into the plot. Another series contains an unfenced plot of the same size as those fenced, which is open to cattle and deer. Records are taken as to the rate of growth, the degree of utilization, and the condition of the vegetation on all three sets of plots. Both cattle and deer are excluded on one plot in order to show the amount and kind of vegetation that the range will support under protection from grazing animals, this to serve as a guide to the management of the surrounding range. The cattle combination plots will show primarily the extent to which deer graze each plant species, and this will serve to determine game palatabilities and grazing capacities. The information will also afford direct comparison with the ungrazed plots, and especially with that grazed by both cattle and deer.

The latter comparison will afford information as to the extent of conflict between cattle and deer in the use of different range plants, a question of great importance in the management of ranges used by both cattle and by deer. Presumably the records in these cattle exclosures and those on the open plots will show that some plants are grazed by deer and not by cattle, a fact pretty well established in various range types. Such data will furnish valuable information in determining use of range by deer and the deer population in relation to the food supply on open range grazed jointly by deer and cattle. Shoemaker believes that this class grazing study would have been more satisfactory had the plots been larger.

Summary of Essential Points

1. The grazing factor may most economically and effectively be eliminated or controlled through the use of exclosures and enclosures. Class grazing may well be studied through the use of exclosure-enclosure plots, so fenced as to permit the grazing of only a certain class of foraging animals.

2. Exclosure and enclosure plots, as well as isolation transects, panel plots, and other such protection or retention plots, are highly valuable in the study of vegetational changes, grazing capacities, seasonal and annual variation in forage production, the gathering of phenological data, in life history studies of animals and plants, and in numerous other ways.

3. The study of plots alone may afford unreliable data upon which to base management plans and methods. All such studies should be supplemented with numerous open range plots and with broad general observations.

4. There is danger of using exclosures and enclosures of such small size as to cause serious experimental error. In regions of medium to heavy rainfall the plots may be considerably smaller (say 1/2 to 2 acres in size) than in the arid Southwest, where several acres, if financially possible, had best be employed. No specific minimum size of the plots is suggested, but they should be large enough to procure reliable detailed records.

5. The most serious factor in the use of the smaller plots is that of grazing by rodents. Wherever possible the smaller plots should be fenced rodent-proof.

6. It is important to map the plots as soon as they are established. The map should show the plant species and their density, the grouping of special communities, and a detailed grazing reconnaissance should be made of the entire area. When convenient a topographic map should be made, particularly of the larger plots.

INSTRUMENTATION

W. G. McGinnies, Chairman

McGinnies: Instruments deal with tangible factors, i.e., the production of figures. On the other hand the interpretation of physical factors in terms of plant or animal response is more difficult.

Time did not permit adequate discussion of instrumentation. Only a few of the broader features of use of instruments were considered.

Precipitation

Forsling: The Great Basin Branch is using the regular weather bureau rain gauges for most of its rainfall records and also tipping bucket rain gauges for intensity of rainfall.

For snowfall, if there is no wind movement, rain gauges serve all right. There is also a question of the accuracy of the Marvin snow gauge in windy locations. In small park areas this gauge gives fairly accurate results. Salt is placed in cans to prevent ice formation.

Weather bureau stations are mostly in the low country while about 95 per cent of precipitation occurs in the high country with but few measuring stations at these higher elevations. There are, however, 53 snow measuring stations in Utah.

Culley: There are 16 gauges on the Santa Rita. These are read weekly and at the end of the month. Ocular observations are made on local storms as to the extent of area covered. More measurements would be better. To prevent evaporation, oil is used on rain gauges and has been found to be effective for a limited time. The weather bureau reports practically no loss from evaporation in two weeks' time. In order to get relation to vegetation the rain gauges are set in soil 6 inches to 1 foot.

McGinnies: Precipitation gauge set to be 3 feet above ground and oil used to prevent evaporation. Roesser, however, used rain gauges set in the ground in Colorado and got good results at high elevations.

Campbell: Suggested use of typewriter oil or paraffin oil to prevent evaporation when gauges are read at intervals.

Lowdermilk: The stick method of measuring rain catch is not accurate in wet weather. He is developing a hoop gauge.

Evaporation

Lowdermilk: The weather bureau pan is not efficient. Dr. Cummings' method is an insulated pan 2 x 2 ft. x 18 in. deep. Lowdermilk has designed a circular one, for which he will furnish blue prints if desired. This pan has a pipe attachment and Mariott feed system. Eliminates every factor except heat intake and loss; wind a compensating factor.

Campbell: On the Jornada evaporation is being determined from a free water surface. The evaporation pan is 2 feet square and 18 inches deep and is floated in the center of a 60,000 gallon steel tank, 5 feet high. The pan is filled to a definite point each day. Two floats keep the pan on the surface of the water. A dipper has been constructed to facilitate accurate measurement of water added to take the place of that evaporated.

Lowdermilk: Where the water table is near the surface, the present methods of soil evaporation measurements are satisfactory but they do not meet all soil conditions. Pans holding water at different depths below surface were tried at Fort Collins, but are not applicable to grain soils. The evaporation zone extends down 6 inches to 8 inches unless water table is near surface. Suggests using pans with 12 inches of soil and measure amount of water going through this soil. A phytometer has been developed for this purpose. The soil is saturated and protected from evaporation at surface. The soil is then drained for 12 hours. Record is kept of water going in and draining through, and at end of growing season determine comparison with amount needed to equal retention ability of soil.

Transpiration

Lowdermilk: Questions use of such equipment as the usual small phytometer. Vichmeyer, of the University of California, has developed tanks 2 to 3 feet in diameter and 6 to 8 feet deep, which weigh two to three thousand pounds with soil. They are equipped with automatic recording devices and give rather satisfactory results.

McGinnies: Uses sealed garbage cans; digs up well-rooted plants and transplants directly. Cotton is plugged around plant stems to avoid water loss there. Water is supplied by two liter flasks and loss determined by weighing. One man can handle 200 such cans in addition to instrumentation. Allowance is made for top growth. The plants are grown in series of six cans for each species.

Soil Moisture

Lowdermilk: We are concerned with available soil moisture. Methods of agricultural soil samplings are not applicable to mountain areas. Volume weight is not a measure of available moisture. There is great variability in water-holding capacity of mountain soils. Uses percentage of moisture equivalent. Pits are dug for each sample and a uniform sample area located. The moisture equivalent is not entirely satisfactory. It is good for loams, too high for clays, and too low for sands.

The absorption method over constant vapor pressure is believed to be a more sensitive measure. The wilting coefficient method of Briggs and Shants varies from 1.6 to 3.4 and this fails to be an accurate measure. He proposes to use the wilting point, indicator plants and sampling root zone.

AN OUTLINE OF METHODS USED IN STUDYING INFLUENCE OF GRAZING ON TIMBER REPRODUCTION IN THE SOUTHWEST.

METHODS OF STUDYING INFLUENCE OF GRAZING ON SAW TIMBER TYPES.

C. K. Cooperrider, Chairman

Project and Purpose

Western yellow pine forests occupy an extensive land area and furnish important timber products. Forage growth in the forest sustains a live stock industry that dates its beginning to earliest settlement. Hundreds of thousands of sheep and cattle and much of the big game supply are dependent on the forest lands for summer range.

Perpetuation of the virgin forest is dependent on natural regeneration in the openings created by mortality of aged trees. Natural reforestation is dependent on reproduction established before cutting, and on regeneration from seed trees provided for by regulated lumbering. Grazing of a nature that is destructive to range has long been recognized as a factor contributing to local failures in securing satisfactory forest regeneration. In other instances, severe browsing of seedlings has retarded their growth. Theoretically, a ready solution of the problem would be had in the removal of the animal cause. Discontinuation of grazing would result in the loss of a forage resource of considerable economic importance. Stock exclusion could not be considered economically sound until other possible measures for meeting the situation had been tried and proven failures. Methods of range management for control of injury had not been developed, since the causes of injury had not been determined.

The purpose of this study was to determine whether the forage resource could be economically used for live stock production with reasonable assurance that grazing would not prevent satisfactory forest regeneration.

Method of Attack

It so happened that the pine lands in the Southwest were more or less intimately known to the writer. There were areas that furnished much conflicting evidence, including those where browsing injury was intense, and others where little or no evident damage to reproduction was sustained, regardless of the degree of range utilization. Certain evidence could be collected here and there to support almost any conclusion.

In selecting locations for intensive investigations fenced ranges were picked that were representative of the most acute state of the forest-range problem on the Arizona plateau.

The primary cattle area selected presented a range of 24,000 acres on which 1,000 head of aged steers were grazed for 5 months. Like many another range on the Arizona plateau, there was no natural water supply. Developed watering places, which were mainly large dirt tanks, were few and inadequately spaced for proper utilization of the forage area. The readily available range, one to three miles out, surrounding each water tank was badly overgrazed. Areas at a distance from water were but lightly used. They could be utilized only during the rainy season when the water requirements of the animal are least and the water content of forage is highest.

The circumstances involved were determined, the range thoroughly known before measures for study were instituted. It was very evident that primary factors for determination were the extent and intensity of injury under known circumstances, i. e. those governing the grazing of the range unit and the points where measurements were taken; the causes for injury and the possible means and practical application of means for control of injury. The methods employed must then be adapted to measure forest, range and animal factors.

The range was considered the unit, for the range, not some particular part of it, is the habitat of the animal.

Sub-projects and Methods Employed for Investigations

Sub-project phases were determined during the developmental stages of the work. Certain sub-projects can only be outlined in detail.

A. Susceptibility to injury.

1. Experimental range.

a. Purpose: To determine amount and character of injury to established reproduction; the period or periods of injury; the circumstances of injury; the relation of the plant association, the character of vegetation, the character of reproduction, etc., to susceptibility of reproduction to injury.

b. Methods of study:

(1) Major reproduction quadrats (grazed plots on the open range).

(a) The number of quadrats was governed by the measurements to be taken. In this instance transportation facilities were such that a maximum of work could be handled. For correlation purposes, 3 to 5 duplicate plots were established in representative areas to measure each condition. The duplicates were located

with the reoccurrence of the condition in widely separated parts of the range rather than grouped at one point. The number of established specimens by individual plots ranged from 20 to 175. Plot size was determined by the local occurrence of reproduction; the average size was about 20 x 40 feet. Each seedling was located and given a number on a plot map; data were recorded by individual specimens.

(b) Reproduction quadrats were located with reference to:

Different associations of range vegetation.

Belts of range utilization - depleted to light use.

Densities of tree reproduction.

Intensities of evident injury to reproduction.

Availability of watering places.

(c) Examination periods.

1. Spring: An examination of plots in May, prior to the entry of stock makes it possible to determine the damage that has occurred since the last examination of the previous year. Injury caused by game animals, rodents, stray stock, etc., may then be segregated for that period.

2. Early summer dry period: Examinations are made during the dry season prior to the summer rains to determine intensity, character, and approximate date of damage. These examinations also furnish records for correlation with the influence of rainfall. Records to date and observations in the field show that annual cessation of shoot damage is concurrent with the first effective rains of the summer rainy season. The determination of the relation of injury to the period of the grazing season, to the state of

the weather - dry or rainy, and to the response of vegetation to climate gave very important results.

3. Summer rainy period: Examinations during the summer rainy period may be limited to determinations of the relation of damage to the influence of rainfall, and to recording the slight injuries sustained during this period.

4. Fall dry period: Needle pulling and occasional shoot damage that occurs in the fall should be recorded as soon after it takes place as is practical. October temperatures usually cause the bench grasses to become chalf-like and of slight forage value. Records should make possible the correlation of injury with climatic influence and forage value of vegetation during the cold dry period near the close of the grazing season.

5. Final examination: At the close of the grazing period an examination of each plot is made and the records for the season summarized.

(d) The period records include the following data for each specimen of reproduction:

The number of the quadrat and specimen.

Approximate date of injury, if any. Experience makes it possible to closely estimate the time of injury inflicted during a 30 day period prior to the examination.

Number and kind of parts taken, as primary leader and laterals.

Cause of injury, such as stock, rodents, insects, etc.

The final records for the season include data on:

Total height.

Conformation, viz., normal, abnormal, bushy.

Vigor, viz, good, medium, poor.

Injury, giving parts taken, intensity and agencies inflicting injury.

Current growth.

Special information of value in analyzing the plot data.

Certain of these data are of particular value for other phases of the study, for example, growth, conformation and vigor are good measures of the cumulative influence of injury.

(e) Photographs of representative plots are duplicated from time to time to record change.

(2) Major reproduction quadrats in panels. In addition to those records on the open range, quadrats were located in a number of fenced panel plots of from 1 to 4 acres in area. Panels are so arranged that the fencing may be raised or lowered to exclude or introduce live stock. Grazing may thus be controlled and still take place in a manner comparable to normal range use. The panel areas are characteristic of local conditions; they are used primarily to control season of use and degree of forage utilization. Growth of forage plants governs the opening of the panel, and use of forage the closing. The panel then affords an indirect measure of the influence of season and intensity of forage utilization on browsing of tree seedlings.

Many are the uses of the results secured in the panels, for example, that of comparison of a panel and any other similar part of the range to determine the effectiveness of range management in practice. Whenever the panel requires a minimum of control, and the results within and outside the panel approach a common average, the optimum is approached that may be realized alone through regulated utilization of forage.

B. Relationship of utilization of forage to tree injury:

We have considered methods for measuring injury, the direct effect of the animal on reproduction. If we stop at this point, if we do no more than record the injury within and without an exclosure or compare the injury on both sides of a fence line, we have simply recorded what can readily be seen; we have done nothing toward

investigation of the circumstances of injury. Solution of the problem would still rest in a number of undetermined factors as the reasons for stock browsing seedlings, the influence of known amounts of browsing, and the limitations of range and stock management in the control of injury.

Overgrazing was one evident cause for tree injury that could be measured, and the measurements correlated with data on reproduction in the major quadrats.

1. Purpose for a study of forage and forage utilization.

   a. To determine the influence of forage utilization on injury sustained by reproduction by measurement of:

      The degree of utilization for current amounts of forage growth;

      The degree of utilization just prior to the summer rainy season and in the late fall dry period - the two critical periods of injury susceptibility;

      And the degree of utilization of the most succulent vegetation (forage with highest water content) at any time injury occurs.

      The initial quadrat studies indicated a close relationship between injury to reproduction and degree of utilization of coarse parts of bunch grass forage. It also showed that on poorly watered parts of the range, over-utilization of succulent parts of forage plants was common during the dry season; and that such over-use was accompanied by severe browsing of reproduction.

   b. To determine the influence of degrees of use of forage on maintenance of the forage plants and of the supply of succulent forage in particular.

2. Methods:

   a. Forage utilization - reproduction injury relationships. Major forage quadrats were located on open range, in panel exclosures and in water relationship pastures.

      Areas surrounding each major reproduction quadrat, each representative of the particular part of the range in which it was located were used. In total all plots were representative of the range. The average size used was 50 x 50 feet.

(1) Character of records and when taken. The following records were taken for each species of forage plant.

Stage of development.

Maximum, minimum and average size of growing parts (stalks and leaves).

State of succulence.

Utilization, expressed in terms of the percentage of plant growth taken.

Records were taken on each forage quadrat at the time the reproduction quadrat within the same area was examined.

(2) Supplemental records were also taken to determine the area limits for which records made on major forage quadrats were applicable.

A utilization map was prepared at the end of the summer dry season and at the close of the grazing period. Preparation of the map data consists of a brief reconnaissance to connect the lines of utilization determined in examinations of the major quadrats.

b. Climatic factors: Injury is very closely related to the influences of climate. Damaging influence from browsing is confined to the dry periods of the grazing season; injury practically ceases under the influence of rainfall that is effective in increasing the succulence of forage. To facilitate determinations on vegetation that are dependent on moisture relationship, a few rain gauges are maintained on the range. Readings are not made daily, but in conjunction with regular work.

C. Relative susceptibility of small seedlings to stock injury.

1. Purpose: Measurements begun in 1927 dealt largely with seedlings of 1919 germination. To complete the record from germination to a height beyond reach of grazing animals provision was made to take advantage of possible growth of seedlings from the abundant seed crop of 1927.

2. Methods:

a. Analysis of data for reproduction and forage quadrats. Germination of many seedlings took place in 1928 and 1929.

Almost all of these died from natural causes within a year after germination. Valuable records were obtained for influences during the initial year of germination.

Since the seedlings were handled in connection with quadrats on established reproduction, data pertaining to the influences surrounding the quadrat also apply to small seedlings.

b. Seedling plots on open range and in panel exclosures.

(1) Number, size, and character. Sections 10 x 10 feet in area in practically all reproduction plots were seeded in 1928 in an attempt to supplement natural seeding. The number of temporarily established seedlings obtained ranged from 10 to 215 to the 100 sq. ft. section; many more died immediately following germination. Almost as many were obtained in 1929 from seed that failed to germinate during the dry year of 1928. Because of natural death loss during the year of germination and the following dry season, plots were established in 1930 on another range where survival was adequate to facilitate work. These plots include seedlings of 1928 and 1929 germination, and established reproduction in amounts sufficient to furnish a comparison of injury for the different age classes.

c. Each young seedling was located with reference to control, furnished by grass tufts, older seedlings, rocks, etc., and given a number on a plot map. This was necessitated by the extended period of germination and by the high mortality from natural causes. Without such control it was found impossible to account for the seedlings recorded on the first count or to separate those from later germinations.

d. Records include:

Injury, if any.

Specific character of injury.

Parts injured.

Causes of injury or death, as stock, rodents, grub, drought, frost heave.

Any information relative to apparent reasons for injury.

Growth development.

Recovery from injury.

Data on vegetation and use of vegetation.

D. Recovery of injured pine reproduction.

1. Purpose:

To determine the processes of recovery and the extent of recovery of pine reproduction that has been injured by browsing animals.

Notwithstanding generally accepted opinions to the contrary, removal of the primary growing points or of current stem-growth during the periods in which browsing occurs does not abrogate development and recovery of the normal form of the seedling pine.

Prior to the initiation of this project no study had been made of the influence of specific kinds of injury or of the cumulative effects of specific injury. In order to classify injury or to grade its effect, it became necessary to know the effect of removal of varying amounts of needle growth from different parts of the plant; to know how much development is retarded by the removal of stem parts; and, to know the response of the plant to injury and the cumulative influence of kinds and intensities of injury over a period of time.

2. Methods:

a. Data from range and panel plots (major quadrats under A).

The records on the open range and panel plots give annual growth, vigor, and conformation for each specimen of reproduction. By an annual and periodic weighing of the growth factors and the factors of injury sustained, the recovery factor for a large number of individuals, for class groups, or for the average of classes in the plots may be traced.

b. Measure of recovery for representative individual specimens.

Specimens in the major quadrats are and have been subject to many varied influences. In order to accurately check the measure of recovery obtained for the many specimens in the quadrats, certain individuals that were representative of the effects of extreme to light intensities of injury were selected for special study. Records in detail were taken to show the then existing state of the specimen. Current records consist of the following:

(1) Parts and amount of parts taken currently by stock.

(2) Growth and character of growth of the specimen.

(3) Method of recovery.

(4) Height growth.

(5) Conformation in respect to trend toward or from a normal state.

(6) Vigor - indications of change in vigor resulting from stock injury.

(7) Records are supplemented by photographs.

c. Cumulative effect of injuries caused by cattle.

A single injury usually influences the plant but little, though it may temporarily retard development. A devitalized or deformed specimen is usually the product of many injuries, the result of cumulative effect of injuries.

In order to measure the cumulative effects of most severe types of injuries sustained annually for a period of years, a sectional plot was established. Certain representative specimens in each section of the plot were selected for intensive study. Each of these had been severely injured, were deformed from past injury. One section of the plot was fenced when established. An additional section is fenced each year. The location and management of the plot is such that injury to unprotected specimens may be secured annually.

Records taken are similar to those described; they include each detail of injury, method of recovery, and growth.

d. Determination of cumulative effects of injury by mechanical means.

Preliminary tests indicated that injury could be successfully duplicated by hand, that the response of the plant following hand inflicted injury was the same so long as it is made at the time and during the stage of development at which the particular kind of injury is done by stock. This made possible a laboratory type of test. Two plots protected from grazing were established. Specimens were subjected to the same natural environment.

Plants on the open range may or may not be injured, or have the same class of injury inflicted on successive years. Mechanical methods allow for the consecutive use of kinds and degrees of injury inflicted after the manner known to be done by grazing animals.

(1) Procedure:

Duplicate specimens that were similar as to size, conformation, and vigor were selected for each test. One of each pair is subjected to injury, the other is carried as a check uninjured specimen.

(a) Injury to leaves.

Needles are pulled in the fall when needle pulling is taking place on the range; needles are broken in the late fall, leaving stubs, when needle leaves are set in the sheath and leaves taken by stock are crushed off, leaving stubs.

(b) Kind and degree of leaf injury.

(1) To leaves on primary leader, laterals or secondary branches, and to combinations of the same.

(2) Degrees of injury (actual count of leaves taken and leaves left) for parts listed above, as leader, etc.

(c) Injury to stems (growing shoots).

Shoots are taken during the period of length growth when stock browse shoots.

(1) Kind.
To primary leader, laterals or secondary branches and to combinations of the same.

(2) Degrees of injury to the parts listed under (1).

Removal of the stem length in amounts as follows:

Growing tip only, leaving many leaves on stub.
One-half stem, leaving many leaves on stub.
Three-fourths stem, leaving few leaves on stub.
To short stub, leaving one or more leaves.

To short stub, leaving no leaves.
Combinations of the above distributed among parts listed under (1).
Injury reproduced in any instance is patterned after examples inflicted by stock.

e. Determination of processes of recovery.

In order to render the measure of the influence of injury of practical value, it became necessary to determine the actual processes of recovery from injury. No literature on the subject was known. No information was available, except that gained through observation while conducting other phases of this study. The bud forms that allow for normal development of the seedling following removal of the stem terminals were discovered the first year of this study. Intensive investigations were then undertaken.

(1) Field determinations.

(a) Relation of recovery to injury (circumstances under which recovery takes place).

(b) Recovery by means of new bud developed in needle fascicle below point of injury on current year's growth.

(c) Recovery by means of latent bud, or new bud developed in leaf scar, both on previous year's stem growth and directly below removed current stem growth.

(d) Recovery by means of adventitious buds developed on older parts of stem.

(e) Recovery by means of extension of uninjured lateral branch.

(f) Relative probability of recovery by methods (b) to (e).

(2) Laboratory determinations.

Histogenesis of the types of buds. A histological and morphological study of bud formation.

E. Susceptibility of pine reproduction to injury from agencies other than live stock.

1. Purpose:

It is very necessary to determine and segregate the injury caused by agencies other than live stock. The source of injury may frequently be correctly identified at the time of injury; it is often an indeterminate quantity at the close of the grazing season. Injury by other agencies often amounts to more serious proportions than does injury by live stock.

Primary agencies of injury are tip moth, rodents (porcupine, rabbit, and small rodents), game animals (antelope and deer), insects other than tip moth, fungi, winter kill, frost heave and drought. Because of its importance tip moth injury deserves careful consideration; it often exceeds stock injury in amount and severity.

Antelope and deer are involved in this study. Game and stock injury are similar; they are not always separable. Tracks of game animals only, damage before stock enter or after they leave the range, recent damage on parts of the range not then used by stock, etc., are evident proof that can be relied upon at least in a determination that the cause of the injury was not live stock.

Fungi or insects may be the evident cause of loss of vitality in the specimen at one season of the year, may not be present at another. Most rodent damage to established specimens may be easily identified; injury to current year seedlings by small rodents may be detected by the teeth marks at the point of injury.

2. Methods:

The plots and specimens used were the same as those employed in other phases of the study.

The data were taken at the time of regular plot examination and on the same form as was stock injury; they form a part of the complete record on reproduction quadrats.

It takes but little more time to complete this valuable record than to take the record of stock injury only.

F. Range and live stock management.

Due largely to lack of control, watered parts of the range had been severely overgrazed in the past. Overstocking had resulted in severe depletion of range accessible to water. Other parts of the range were reached by stock during the height of the rainy season only; cattle will then travel far from water and graze for days before returning to a watering place.

The situation could be helped by possible distribution of salt; however, it would have been necessary to reduce stocking from the basis of all forage on the range to that available to watering places, or to provide additional waters that would render unused feed available.

1. Purpose of management:

To improve range and forest conditions by regulation of range use. This is being accomplished without a reduction in the number of stock on the range.

In addition, it is the aim to make this range, which represented a most unsatisfactory condition in range and forest management, a demonstration of what may be accomplished through simple and economic methods of range management.

2. Methods:

a. Water supply:

Because of the character of volcanic formations, there are no natural surface waters on the range. For the same reason, possible well locations are very limited; well water is extremely uncertain. Dirt tanks are the common means employed, the most promising method of water development. Heretofore small dirt tanks have never been given thorough trial. They have been considered uncertain on account of the amount and temporary character of water supply. Some large tanks are necessary to insure a permanent water supply. Locations that will insure permanent water are very limited, and would not adequately water the range if developed. Large tanks are expensive to construct and maintain. In an attempt to supplement permanent watering places, several small dirt tanks were constructed early in the study. The measure of success obtained with these justified the construction of additional ones. Selections for tank locations were carefully made. The possibilities of success in obtaining water supply, of making it most effective, the feed made accessible in relation to cost are factors that govern tank locations.

b. Water control:

Watering places, particularly the permanent waters and those in areas that have been overgrazed in the past, have been fenced as funds would permit. Water lots are well fenced and equipped with adequate gate facilities so that the use of waters and the area of range accessible from them may be controlled.

On the average, an adequate supply of water is available in the small tanks during the rainy season, and through most of the fall period. Some of the small tanks have supplied water at other times. Cattle are inclined to use the good feed areas whenever water is available. By control of the permanent waters, cattle are practically excluded from the old overgrazed areas during the forage growing season.

Stock have benefited by this change and the improvement in the vegetation and the reduction in amount of injury to reproduction on range formerly overgrazed is most encouraging.

The cost of water development has been small. It is believed that cost has been more than offset during a single season of use by the resultant gain in weight of steers.

(1) Procedure:

Regulate the use of watering places to secure the best use of range from the points where water is available and to the advantage of the areas formerly over-utilized. This will ordinarily mean that permanent waters be kept open for use during the early summer dry season and for a short period before the close of the grazing season.

The water control program during any grazing season must necessarily be adapted to circumstances of that particular year.

c. Salt control:

Management of salt grounds is an effective means in the control of movement of cattle and utilization of range.

In this study, reproduction injury was found to be particularly severe where salt was used during dry periods to draw cattle into feed areas at a distance from water. Availability of water governs any management of stock to secure a desirable use of the range. Salt can be used as an effective means in securing distribution of stock within the limits prescribed by available water supply. The purpose of salt control is to determine the means of salting that are most effective in securing desired utilization without unduly adding to the travel and thirst of the animal, factors that influence browsing of reproduction.

A detailed salt plan has been developed. It is based on the following principles:

(1) Salt the forage areas to be used at any particular time and not the areas subject to concentration of stock around water.

(2) Dry season. Salt the forage areas readily accessible to available water (usually permanent waters) during the dry season, the period when water requirement of the animal is highest, water content in forage is least, and reproduction is most susceptible to injury.

(3) Rainy season. Salt the forage areas least susceptible to overuse (those that have been made available by temporary water supply) during and following the rainy season, the period when water requirement of the animal is least, when the water content of forage is high, and when reproduction is least susceptible to injury.

(4) Change salt grounds as often as necessary to secure the utilization desired and to avoid local overuse.

d. Handling stock:

The advantage gained through water and salt control may be increased by management of stock.

One resident range rider has been maintained by the owner of the stock.

Steers in particular are inclined to collect in groups, to travel at random over the range. A drift to particular parts of the range is common during certain seasons. At these times steers may congregate along a boundary fence in large numbers.

Not much work of this character is necessary except at certain periods.

The main value obtained from a knowledge of stock movements is that of being able to meet the emergency immediately.

Control of the movement of stock by a range rider should supplement the influence exerted through water and salt control. The following are examples:

(1) Remove the stragglers from areas accessible to waters that have been closed and from areas of heavy utilization.

(2) Counteract the exceptional drift and the concentration that results from drift at certain seasons.

(3) Aid the movements of stock caused by salt and water control when necessary.

General results:

The program outlined may seem to be a formidable one. No small effort was necessary to carry it out. It has given the measurements required for an understanding of the local problem, and has resulted in determination of basic facts that should apply to similar problems elsewhere.

Certain results were mentioned in the explanatory notes accompanying the outline. A very few others may be necessary to indicate the value of the methods discussed.

The data on major reproduction and forage quadrats yielded such basic facts as these:

> There are two main kinds of injury by live stock; they occur over two distinct periods of the summer grazing season. Browsing of shoots (stem terminals) takes place in the latter part of the early summer dry season during the latter two-thirds of the period of stem elongation. Browsing of needle leaves may begin in late summer; it occurs mainly during the late fall dry season. Browsing of either shoots or leaves is almost entirely confined to the current year's growth; it takes place prior to maturity of the growing part.
>
> Over grazing is one of the primary causes for browsing of reproduction.
>
> At the close of the grazing period in the fall, it may be very difficult to recognize overgrazing that has taken place during the early summer dry season. Close use, or depletion, of the growth of succulent forage prior to the beginning of the rainy season is the particular kind of overgrazing that causes severe shoot browsing.

Overgrazing is but one of the primary causes for injury. That water deficiency is a primary cause for injury was indicated by all phases of the study. Water relationships are under investigation in experimental pastures where water supply is controlled. Tests during the past season corroborate past indications.

Inadequate spacing of permanent watering places and a forage supply that is of low succulence during the dry season (the result of overgrazing, and heavy cutting of timber) are all factors that are subject to control. Considerable evidence was obtained that certain other environmental influences govern the feeding habits of the animal. For example, animals subject to starvation influences on depleted winter range have been forced to feed on shrubs that otherwise would not be eaten. It is very evident that some of this browsing is to satisfy thirst. The animal enters the summer range in poor condition and also with an acquired ability to utilize inferior forage and obtain water by feeding upon plants of high water content. There are probably some distinctive local causes for injury wherever severe injury is suffered.

The work on recovery of injured seedlings has measured the influence of specific injury and the cumulative effects of injuries. It has determined the ability of the seedling to resist injury and the processes of recovery from injury. Special investigations have shown that recovery from specific injury is governed by the relation of time of injury to stage of current growth. It so happens that injury inflicted by live stock occurs well within the limit of time required for recovery.

The use of a characteristic range unit for experimental purposes has made possible the practical trial of range management methods developed and the actual measurement of their effectiveness. It may be gratifying to know that the methods of range management used are economically feasible and that the practices found most advantageous for forest betterment are also to the best interests of range and live stock.

It should be at least mentioned that adaptations of these methods were developed for sheep range during the same period the study on cattle range was in progress, and that the results obtained give promise of a satisfactory solution of the problem.

Chapline: The late Douglas C. Ingram studied grazing on cut-over Douglas fir lands mainly from the standpoint of what range management would give the most satisfactory fire protection. Douglas fir is practically clean cut and the slash is burned, following which reproduction usually comes in abundantly. A great quantity of weeds, some of which are highly inflammable also appear. If a fire should run through these weeds, it would kill out the reproduction and its reestablishment is then very uncertain. Ingram studied the changes which occurred in the plant cover on these cut-over areas, the value of the different species under the various conditions for grazing, how closely the range could be used without undue damage to the timber reproduction, and how grazing reduced the fire hazard. In his main intensive studies of the problem he used a transect on which he could record the character and utilization of the vegetation, the degree of damage to reproduction, and other influencing factors. This transect ran through 7 different conditions resulting from burns on a typical Douglas fir cut-over area.

Ralph K. Day has been studying the problem of grazing in woodlots of the Central States. Since woodlots vary so widely throughout the Central States region and the character and degree of grazing varies so greatly, a general survey of the problem was made. Specific records were kept regarding the character of the woodlots, the character of the grazing, and the influence of grazing on regeneration. After completing this phase of the study, several more intensive phases have been taken up, including the study of recovery of the woodlot after grazing is removed, and a determination of what is the proper grazing capacity of one important type of woodlot. This phase of the study is handled in cooperation with the Purdue Agricultural Experiment Station. Three pastures of 6, 12, and 18 acres are being grazed for a 6-month season. Three steers are grazed in each pasture in order to eliminate the individual differences between steers.

METHODS OF STUDYING INTER-RELATION BETWEEN GRAZING AND SOIL EROSION

C. K. Cooperrider, Chairman

Forsling conducted the group over the Great Basin erosion study areas. The results and some reference to methods are given in U.S.D.A. Technical Bulletin 220. Two areas designated "A" and "B" each approximately 10 acres in size. Plan of study was to take these areas in their original condition, A with 16/100 density and B with 40/100, and graze both for a series of years so as to hold the vegetation constant, then to protect A from grazing and aid revegetation so as to increase vegetation on it as rapidly as possible until it had about 40/100 density after five years of such treatment. Since then Area A has been lightly grazed in fall. Area B, near by, is used as a check against the results from A and has been grazed each year so as to keep the vegetative cover as 40/100. All runoff from each of these areas passes through silting basins at the lower end and is measured by volumetric determination for that remaining in the basins and by a record of the water which runs over the weir. There are 2 rain gauges on each area and a tipping bucket gauge between them. Seventeen snow stakes are used to get average depth and water content. A detailed map was made in 1912 and the areas have been mapped at intervals since, both for topography and vegetation. Quadrats and major plots are used to determine specific change in the vegetation. Levels have been run on special courses to check change in soil level.

The method does not determine subsurface runoff, interception or evaporation, but it has determined some of the essentials. A record has been kept of wind velocity, sunshine duration, and temperatures for such interpretation as they deserve. Temperature is important when snow melts. There is a great difference in runoff from year to year as a result of rapidity of snow melting.

On Erosion Area A the catchment basins consist of three compartments, two 12 x 12 feet and one 6 x 12 feet. An 18-inch 90 degree weir makes possible measurement of height of water running over the weir by a float and stillwell hydrograph. One storm overtaxed capacity of the equipment. Small flows of mush ice block the weir outlet and give a reading a little above the true level. The water and silt in the compartments is measured direct. Then flood gates are opened and the material flushed out, their bottoms being sloped to facilitate this. Heated asphalt is used to stop leaks. Oil is used in the stillwell to keep water from freezing. The system of compartments results in the material being sorted in the different compartments, the heavier material dropping in the first.

Sampson: The three compartments were used so as not to have to work over so much area, and also to get sorting of material. In the early days it sometimes took five days to empty the basins. Now with flood gates there is very little trouble.

Cooperrider gave a short description of an inexpensive method of determining surface stability and rapidity of change during processes of breakdown or reconstruction by measurement of surface profiles. The two

extremities of a station were marked by pipes set in cement. A horizontal plane was established between the tops of the stakes by means of a steel tape graduated in hundredths of a foot and stretched to the same hundredth of a foot interval for each subsequent measurement. Vertical distance between the horizontal plane and the many points that form the surface profile are determined by tape and plumb bob. The sum of the readings divided by the number of readings gives the average distance between horizontal plane and surface. Subsequent measurements taken at the same points may be compared in average or for any part of the profile as gully, regular surface, etc. These stations have been used singly for measurement of change in gully or regular surface, also in series at the base of a slope and across small drainage areas at various points from source of flow to point of discharge. Naturally, the eroded material passing over the profile line can not be determined, however, rapid building and cutting or alternate building and cutting can be accurately measured. The greater the fluctuation in change the greater the degree of disturbance.

This method was developed on areas that had been mapped to determine existing vegetation and to follow trends in regeneration or destruction of vegetation. Meter wide transects were also mapped along and up hill from the line of profile to determine the immediate influence of herbaceous vegetation.

Lowdermilk: Vegetation and soil have an inter-relation of long standing. There are three factors: the mantle of vegetation, the fauna, and soil developmental processes, which assume in undisturbed condition an equilibrium. In studies of runoff and erosion we need a concept of undisturbed condition and should have enclosed areas for this. I have been interested in alterations from burning, grazing, etc. In China, Temple forests have not been used much and they give a picture of original conditions which can be compared with other areas. In first work measured the runoff from small watersheds of about 50 acres but the runoff was too great. In more recent studies have used 1/40 acre plots, bordered by boards, on uniform slope, in pairs, with tipping bucket arrangement to measure runoff. Also uses electrical contact and Bristol recorder with 10 to 20 pens to record intensity of rainfall and runoff on same sheet. The tipping bucket capacity so far used is 1/10 cu. ft. but is trying out 1/2 cu. ft. They need to be self-cleaning. In freezing weather they might not work. One can either isolate factors or put in a greater number of plots. We should run laboratory type as well as large plot experiments. My studies are in duplicate to quintuplicate. The results between burned and unburned areas are tremendous.

Renner: On Boise a Range and Erosion survey was made to collect information on what is causing the erosion and what might be done about it. The area was mapped into four erosion classes: (1) areas without accelerated erosion, (2) sheet erosion (the largest class), (3) sheet and light gully erosion, (4) serious gully erosion. All factors such as vegetation, degree of slope, rodents, accessibility to livestock, etc., were recorded for each erosion class. The data have been coded and tabulated with the Hollorith machine and are being analyzed to find out just what conditions promoted or retarded erosion.

Lowdermilk: Vegetation is a measure of maintenance of soil conditions. Soil is also a very sensitive measure of condition of watershed. We need more soils work.

Chapline: We must, of course, determine as definitely as possible what influence range vegetation of different densities and different compositions has on runoff and erosion under the various soil and climatic conditions. Since the vegetation will, in most instances, be grazed we must determine also the influence of different intensities and types of grazing of this vegetation on runoff and erosion.

METHODS OF STUDYING WILD LIFE

W. P. Taylor, Chairman

Taylor: There are very important relationships between animals to other phases of the range problem. The entire research program is related to animal life. Cooperation is accordingly necessary. The tendency is to classify vertebrates as harmful or beneficial. Most are both; we must determine the true status of each. We also need more attention on economics of wild life. The problems are more difficult than those of the chemist and physicist.

Weese: Insects comprise more than half the weight of animals on the globe. They build up their bodies at the expense of plant material. Quantitative studies of insects are extremely difficult. Yet the composition of insect population on overgrazed and lightly grazed areas may be extremely important. In studies made no predominate insect in either case was found to be predominant in the other. There were at least ten times as many insects in the overgrazed area as on a similar one ungrazed, due to different palatability of vegetation, and to composition and rankness of growth. The bare ground is of value to insects for laying eggs, etc. Likewise the climax vegetation is less infested by insects. Forage consumption by insects is hard to get at. Insect enclosures almost impossible to provide. One might be able to construct temporary enclosure and put in a known number of insects. It may be necessary however to carry on this phase of the problem in the laboratory. Climatic changes bring about very different insect numbers and these relationships deserve close study. Soil insects have been studied little here; in England some work has been done on this phase. Such insects greatly alter the texture of the soil. Exclosures eliminate effect of grazing and fertilization; may not be important but may introduce a change.

Lowdermilk: Zoologists should develop a method for studying insect fauna of soil. Changes of percolation are more dependent on plant and animal life than upon the texture of the soil.

Weese: In a meadow soil the underground population was found to be many, 100 to 1000, times as great as that above.

Chapline: The great fluctuations in numbers of rodents in different parts of a range and between years, have caused many difficulties in the analyses of range research data. We can, in part at least, determine the amount of feed taken by rodents in or around livestock exclosures by establishing rodent exclosures. For every exclosure, however, we usually have many open grazed plots under the various range utilization conditions where it is impossible to determine the amount of forage that is taken by rodents. When there is abundant forage, the amount taken by rodents is probably not sufficient to seriously affect research results. Examples have been noted where rodents ate the crowns of plants on small plots of range which were fenced, after a certain degree of utilization had been obtained by cattle, completely upsetting the results which it was aimed to secure. It is likewise extremely difficult to determine proper grazing

capacity for livestock on range pastures where rodents are excessively abundant, and yet vary in intensity of population. Should we endeavor to control these rodents by poisoning and thus largely eliminate the rodent factor on experimental ranges on which we are endeavoring to study various types of livestock grazing alone?

Horn: Pocket gophers may become very abundant and destructive. On the other hand, they may be a benefit; they enlarge burrows daily and are destructive to vegetation while digging, but later benefits may arise. We need to give question rational consideration. Rodents respond to range conditions both as to life habits and to control measures; early in year take bait high in carbohydrate, later high in protein. After several generations animals become more difficult to poison. Some species can be held in check by animal poisoning, other animals must be removed entirely. Need to know the place of each species in entire scheme of range preservation.

Yellowstone National Park Elk Study

By W. M. Rush

Objective: Management plan for the Northern Yellowstone elk herd.

Determine carrying capacity of winter range in terms of elk, deer and antelope - find out best methods of keeping elk herd within limits of carrying capacity - determine rate of increase in herd in order that surplus above carrying capacity of range is known in advance - life history study - diseases affecting wild animals - relationship of wild life to man and domestic stock - food requirements of elk - artificial feeding and salting of elk - relations to predators - recreational value - causes of severe overgrazing of parts of range.

Methods: Field work: checking distribution on range - observing food and other habits - collection and identification of plants eaten - photography - gross dissections of diseased animals - study plots on range - counts of wild animals.

Laboratory: Post-mortems, Crocker, U. of Penn. technique, cultures from pathological lesions, parasites collected, pathological tissues collected, weights and measures - herbarium - photography - records.

Results of Methods: But little progress in carrying capacity studies - unsatisfactory results in counts - life history studies, satisfactory - rate of increase study, unsatisfactory - disease studies, satisfactory - relations to predators, satisfactory - food habit studies, satisfactory - artificial feeding and salting studies, satisfactory - photography, satisfactory.

Outline of Study of the Jackson Hole Elk

O. J. Murie

The study of elk in the Jackson Hole involves an area in which vegetation is normally luxuriant and methods must differ somewhat from those in use in more arid regions. It is sometimes difficult to discover utilization in heavy vegetation, and seldom does one find conditions approaching complete utilization.

The work on the elk has been so extensively taken up with the disease problem that I have had too little opportunity forthorough range studies and certain phases of the range problem have been necessarily neglected.

The following outline, however, will indicate some of the work performed and some of the problems confronting us:

1. Palatability Studies

In conducting these studies I have found it difficult to follow some of the methods used by the Forest Service, in detail, although the general plan is followed.

A herd of elk is located, feeding on a given area. The animals are observed, to note their feeding habits, their manner of cropping plants and their various mannerisms. This information sometimes proves valuable in the interpretation of data.

When the elk have left, a sample area, of any convenient size, is marked off roughly and the composition of the vegetation is determined, as accurately as possible.

Having listed the plant species, with estimated percentage of each, the species grazed are indicated and the percentage of utilization of each estimated directly. Use is so irregular and intermittent and the forage frequently so luxuriant that it is impractical to make actual count of plants, although in certain instances this can be done.

By repeating this process on numerous occasions one obtains a fair set of averages, indicating the relative palatability of many plant species.

By taking careful note of relative availability of plant species, more accurate results are obtained. Some species which are easily available are consistently avoided. Some species are rare and one can not determine their palatability with any precision.

Stomach Contents

At every opportunity samples of the stomach contents of animals at all seasons of the year, are obtained and these are analyzed by the Bureau of Biological Survey in Washington.

These two methods, direct field observation and the analysis of stomach contents, serve as a check on each other. In numerous instances I have found that both methods are required and that if one alone is used, results are unreliable.

Illustrations. During investigations of caribou in Alaska upwards of 30 stomach samples were analyzed. Upon compiling the data I was surprised to note that certain important elements in the caribou diet were not represented in the stomaches collected. The date, the vegetation type frequented by the animal at the particular time it was killed and climatic conditions all influence the percentage and kinds of plants in the stomach.

On the other hand, analysis of stomach contents have proved a decided check on field observation. During a certain period I was under the impression that elk were not feeding on grasses to any great extent. Reference to results of stomach analysis revealed the fact that grasses were the chief item during a similar period. I then found that utilization of grass by elk is often difficult to observe. Frequently only a few blades on a plant are cropped and the flower stalks left standing. On several occasions I have watched an elk at very close range grazing vigorously. I have marked the actual spots where the animal appeared to be taking the bites. After a period as long as five minutes I have rushed out while my notations were fresh in mind, and then been able to find only an occasional plant cropped. The bulk of the feeding could not be detected in the vegetation. This is a very real problem in the observation method. However, by recognizing this difficulty and applying myself more closely, I was able to bring the results of observation more closely in agreement with results of stomach analysis.

Plant Analysis

I have felt that a better understanding of palatability may be had by chemical analysis of plants. Samples of a representative group of plant species eaten by elk as well as others consistently avoided, have been analyzed. This work has not been completed but it is hoped that a study of results may indicate what influences the animals' choice and may furnish other information. Soil studies, with reference to chemical composition of plants, carried on in different localities may give some indication of factors which influence distribution of animals.

This phase of the study has not been completed and actual results have not been obtained.

Unusual Incidents

One should be alert to seize upon any unusual incidents which throw light on the food habits of wild animals. The following examples are taken from unpublished manuscript of the Biological Survey:

On one occasion during the investigation of the Alaskan caribou I saw a caribou feeding in a willow bush on an open gravel bar. When the animal had wandered away I hastened to the spot and discovered that a

willow and an alder bush were growing in close proximity, with the limbs intermingled. The caribou had nipped the buds and catkins of the willow but had consistently avoided the alder buds.

On another occasion I found a yearling caribou which was blind in both eyes. It heard my approach repeatedly and dashed off several times in panic, but did not go far due to the difficulty in traveling. It did not have my scent and was not actually terrified. Once it started off as usual, but suddenly stopped, its muzzle swung to the ground and it began feeding on a patch of Arctostaphylos uva-ursi. I watched it frequently seek out other patches of this plant and Empetrum nigrum, using its nose entirely. This animal and some other were killed. In due time stomach analysis indicated that the blind caribou had fed on the same food as its neighbors which had good eyesight. This was conclusive proof of the important function of the sense of smell in feeding.

In conclusion, I would stress the importance of direct observation of wild animals in the study of their food habits, combined, of course, with all possible laboratory studies.

2. Carrying Capacity

Ascertaining the carrying capacity for elk of a given range is a difficult matter. In the Jackson Hole region, as already stated, vegetation is luxuriant and is not utilized to capacity. This might apply fairly well to winter as well as summer. In summer the animals are scattered over a large area, precluding heavy utilization anywhere, while in winter snow conditions make much of the forage unavailable, although of course there is heavy use in certain favorable areas of concentration.

So far no progress has been made to determine carrying capacity of elk range. This will vary with different vegetation types and in different localities. To construct fences for elk on suitable areas is too expensive. There is one plan which I have been considering and which I should like to submit for discussion on this occasion, with a view to discovering its drawbacks.

It occurred to me that one could select measured areas on the summer range, cut the vegetation, dry it, weigh it, then feed it to captive animals of known weight. Having determined the amount of dry feed required per day, or other desired unit of time, this might be readily translated into acreage.

Definition of Carrying Capacity

By carrying capacity I presume is meant the number of animals a given area can hold without detriment to the vegetation. I feel that this matter requires the most careful consideration. The same measuring stick should not be used in all cases.

Pastures for domestic stock are used in a manner which would be unsuitable for wild game range. Considerations of terrain, climate and similar factors would give a variable figure for the degree of utilization desirable in different localities.

We have become accustomed to remarking that there is "plenty of summer range for the elk" implying that the summer range could carry a great many more elk. Yet this matter may not be as simple as one might suppose. Although elk eat a large variety of plants, they are selective, in their food habits, and seek out certain plant species. It seems logical to conclude that were the numbers of elk increased to something even less than we would ordinarily determine as the carrying capacity, certain favorite and valuable plant species would suffer, even though the general vegetative cover did not show excessive use. If certain very desirable plants were eliminated from the flora or reduced to unimportance, the distribution of the animals might easily be affected. Shifting of the herds might be detrimental to the plans for game management.

Another question, on which I do not have sufficient data, is the amount of plant material which should properly return for the enrichment of the soil. Some portions of the game range consist of rather primitive soil, carrying a flora consistent with such environment. Such soils probably would be greatly improved by a liberal addition of annual plant debris.

Erosion, of course, enters in, and probably other obscure factors which affect plant succession and maintenance of the soil.

I am speaking now of what is known as game ranges, where economic pressure is not severe and where we have opportunity to approach more ideal methods.

In conclusion I would recommend that we do not attempt to carry too large a game herd in a given area, in spite of the demand for more shooting; that we should be cognizant of the ecological factors and possible results, and rather err liberally on the side of under-utilization.

TERMINOLOGY

R. S. Campbell, Chairman

Campbell: The time for this discussion is so limited that it would be well to confine our remarks to questions of policy rather than to discuss definite terms, except for illustration. Since Dr. Weese appointed the Terminology committee of the Ecological Society, he is the logical person to open our discussion, particularly the ideas which he had in mind when he appointed the committee of the Ecological Society.

Weese: The idea of a terminology committee, within the Ecological Society was brought up to establish a clearing house for terminology. Since everyone who writes a new text brings out a new classification, we are interested in an attempt to unify terminology, especially to break down the lines between plant ecology and animal ecology. The distinction is too artificial. Workers separate the two but we must recognize that plants and animals are interdependent and that we cannot speak of the two separately because living organisms all react on one another in a biotic community. I am not in favor of calling a spade a geotome but we do need terms. We do not have definite categories and the result is confusion. The only way out is by working on the subject and I hope that the men in range research will cooperate closely with the terminology committee of the Ecological Society.

Taylor: It is a significant and unfortunate fact that there is all too little agreement among those ecologists who have suggested ecological classifications. While standardization of concepts and terms should not be carried too far, nevertheless the leading ecological concepts ought to have a definite connotation.

Most of the classifications proposed up to date have had a pronounced bias either toward plants or animals. There is need for the replacement of animal ecology and plant ecology by ecology, or bio-ecology. As evidence accumulates it appears more and more likely that the true communities are not animal communities, or plant communities, but biotic communities, including both plants and animals.

The disadvantages of the artificial separation of plant ecology and animal ecology are not only theoretical but practical. I recently worked over the curricula of more than twenty forest schools with this point in mind. Plant ecology is usually given in one department, animal ecology in another. In one school there were courses in plant ecology, animal ecology, and forest ecology, each in a different department, with, apparently, little attempt at correlation.

Range problems, silvicultural problems, and wild life problems are phases of one great problem, that of the ecology of natural resources. Our various management programs will be adequate in proportion as we can see their relations to the ecological problem as a whole. Our ecological terminology should be so applied as to be most helpful in this regard. This means that, so far as practicable, the terms should be bio-ecological, rather than restricted to animals alone or plants alone.

Chapline: There is a real need for ecologists to get together on terminology. Range men probably have been thinking too much of the forage, although they have attempted to correlate their terminology with foresters and workers in wild life. Doubtless the range men have not sufficiently considered the needs in terminology throughout the whole ecological field. Dayton has prepared a glossary of common botanical terms used in range research, but this is practically entirely from the plant end. However, it offers something on which to build.

Sampson: Dr. Taylor is partly justified in saying that foresters have not been entirely fair in their treatment. In fact, I have had to make up mimeographed sheets of definitions for students because text definitions are not satisfactory.

Hanson: There are certain things to consider in recommending terms:

1. Until a concept is clear a term is not needed.
2. Past and present usage of a term in the literature should be studied.
3. Good English words should be used as much as possible so that the science will not become too foreign to the layman.
4. Derivation of a new term should be carefully worked out.
5. Give everyone that is interested opportunity to comment on terms.

Lowdermilk: When a worker gets a concept, he needs a term and unconsciously gives a term to the concept. Following this procedure, I have coined a word or two without submitting them to any committee, such as: "geologic norm", "accelerated erosion", and "erosion pavement". Such terms should be submitted to a committee for consideration.

Chapline: Any committee set up for consideration of terminology should conduct such research as is necessary to determine the most suitable terms to use.

Forsling: There is a tremendous need for a centralized organization or headquarters for standardizing terms used in range research. It is a new field in which many terms are needed, likewise there are many workers, at least a number of whom seem inclined to want to coin new terms of their own without regard to their suitability or adaptability in all respects or to the terms someone else may have been using for the same thing. A clearinghouse is necessary for eliminating confusion. At times it may have to be somewhat strong-armed. The Ecological Society or some other organization should be authorized to "lay down the law" in the final acceptance of a term. The terms should be as simple as possible. Reasonable, every-day descriptive language should be used wherever possible and "high-brow" terms should be restricted as fully as possible.

McGinnies: Foresters and Range men should take an active part in working on this subject, especially as it pertains to ecological concepts and classifications. This group is interested in a practical quantitative type of ecology which may differ in scope and concepts from that of workers

in fields of pure research in some other region. If ecology is to develop along lines of grazing and forestry it is necessary that the language develop along with it. It behooves us then to see that terminology fits our needs as well as those of the eastern ecologist.

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NOMENCLATURE

R. S. Campbell, Chairman

Chapline: The Forest Service early required men concerned with administration of range to know the important plants on the range. In the early identifications of range plant specimens in the Bureau of Plant Industry, wherein resides the authority for scientific plant names used by the Department of Agriculture (save for the use by the Forest Service of the Check List nomenclature), various synonyms were often given for the same plant. Those who sent material to local botanists got still different names. This was largely the result of the use of two codes of nomenclature and different generic and specific concepts. Considerable confusion has resulted and emphasized the necessity for standardization. The systematists of the Bureau of Plant Industry who handle our range plant material have now, with few exceptions, come to appreciate and sympathize with our point of view, a more conservative concept of genera and species has come into vogue, and in general we are now receiving earnest cooperation in our objective of a stable Latin nomenclature. The collection of additional specimens of little known plants and other field studies, have aided. W. A. Dayton, in charge of range forage investigations in the Forest Service, has cooperated with numerous taxonomists at institutions. Many taxonomists preparing monographs have consulted with him and other Department botanists.

As to common names: The Forest Service has a committee for consideration of names for trees. There is also a standardized plant name committee for plants in the horticultural trade, of which Dr. F. V. Coville of the Bureau of Plant Industry is a member. Common names for range plants are rather hard to standardize. Each locality wants to hold to the names inuse. A typical result is that there are probably 15 different species called buck brush. On the other hand, the same plant may be called by several to many names. In endeavoring to standardize common names in use by the Forest Service, we have tried, in so far as possible, to accept the most satisfactory and widest used name, especially if commonly used in publications. Whenever possible local names have been used. The Intermountain Region, in cooperation with Dayton, has developed such a list of plant names. The present Government Printing Office requirement is to use names based on the following priorities: (1) "Standardized Plant Names", except for (2) forest trees found in Sudworth's "Check List", (3) the Government Printing Office "Style Book", and (4) Webster's Dictionary.

Shoemaker: We need a list of common plants for use by non-technical men and stockmen. We have prepared a tentative list of the more common and more important species that occur in the Southwestern Region, arranged alphabetically by common names. An attempt was made to standardize the common names as far as practicable by reference to "The Grass Booklet", "Standardized Plant Names" and "Webster's Dictionary". However, it is believed undesirable to entirely standardize common names throughout the West. The Spanish language has given many good common names to plants in the Southwest that would not be applicable nor understood elsewhere. On the other hand, they are so satisfactory and of such general use throughout the Southwest that it would be a mistake to replace them by names that may be in general use in other regions of the West.

Hatton: We adopted a list of common names for plants in the Rocky Mountain Region in connection with our palatability tables, but these in all cases are listed with the scientific names. For some years I have felt the need for a simple pocket size booklet for field men and during the past winter we undertook the preparation of such a booklet for the Rocky Mountain Region. Our idea back of such a booklet may be stated under four principal headings:

1. Practical aid in range management from the standpoint of forage recognition and evaluation. It is not our idea that we should go farther than that in the subject of range management, which is handled in other ways.

2. An aid in training new men, especially in administrative positions.

3. Something of interest and value to stockmen, principally our range permittees and cooperating agencies, such as the Biological Survey.

4. A simple non-technical treatise stated in understandable terms to those who are not especially trained in the more technical botanical keys.

The booklet is to be illustrated with cuts and photographs of plants, and so arranged that the field men will easily find the answer to the ordinary every day questions that arise with reference to plants in their range relation, both as to their group names and relative forage value.

Sampson: I am in favor of standardization. The common names should be closely correlated with scientific names. For example: Smith's Wheatgrass (Agropyron smithii).

Chapline: The American Joint Committee on Horticultural Nomenclature, a committee of three which selects the standard plant names for the horticultural trade, adopts a generic common name in so far as possible.

Hanson: There is considerable danger in various offices preparing lists of plant names for limited use. The common names that are used in a region should be as uniform as possible. For example, it is desirable that the names used in the manuals and in the Forest Service lists should agree. Otherwise the schools in a state, say Colorado, may be teaching a different set of names than the one used by the Forest Service. If the Denver office is preparing lists of names, should not all possible sources of information in Colorado and Wyoming be tapped?

Pearse: Because of the difficulty encountered sometimes in recognizing systematic species, might we not use ecological species or group ecological equivalents together? This should speed up the work and give a more exact picture of the vegetative composition than if systemic genera were used.

Stewart: Taxonomists often are faced with the problem of how to divide species, especially when hybrids come in and cause difficulties. Genetic bases show these relationships. Species have been found to hybridize freely: e.g. oaks in Minnesota where one species (so-called) was shown clearly to be a hybrid between two others. The same was found for violets in Vermont. Suppose Agropyron inerme and Agropyron spicatum would cross there would be a whole range of intermediate forms which some taxonomists might want to make into species as in oaks and violets . The chromosome number may in some cases need to be called on to help in speciation.

Campbell: Serological investigations with the use of agglutination tests have been under way for a long time in Europe to show genetic relationships, and are now being employed in this country, especially in plant pathology.

Becraft: I wonder if we aren't going too far in trying to bring the systematist to our terms. He might want to bring us to his, so perhaps we should take middle ground. Furthermore, are we not paying too much attention to common names?

Hanson: Dr. Aven Nelson is working on a new dual purpose manual. He has realized the need of names for finely delimited species and for large species for broad field use.

Chapline: Dr. Clements is studying the species question from the standpoint of ecological forms. He has grown the same plant species under different habitat conditions and noted considerable variation due to the ecological reactions.

Clawson: From the standpoint of the poisonous plant investigator an accurate determination of species is very important. Closely related species may vary greatly in toxicity, e.g., Zygadenus, -- Senecio the same way: Astragalus the same. Even varieties may show some difference. Lupines give a great deal of trouble, some are poisonous to sheep, and some to cattle, while others are good forage.

Cooperrider: Lists should be made so we can find names and make use of them, index if necessary. We should have an accepted name and synonyms for discussion.

Chapline: In publications of the Department of Agriculture that are to be available for general distribution, the policy is to use one common name supported at its first appearance by its scientific name. It is permissible, of course, to mention in the manuscript other common names by which the plant is known.

Eggleston: I was much interested in the suggestion that ecologists make "ecological" species. What is an ecological species? Answer "there ain't no such animal." My frank belief is that ecologists have too much to do without manufacturing species of their own. Brought up in the old "systematic school" but with friends interested in ecology, genetics, etc.,

I have been sitting on the side lines for forty years now watching events and also taking an interest in the work my friends are doing. No one is a first class systematist unless he knows something about the allied subjects in botany, chemistry and physics. Conversely a capable ecologist is not made without some accurate knowledge of systematic botany. It would seem as though the biologists of forty years ago ran wild on the various subjects they took up and forgot that the foundation for all work in plant biology is the various species etc., that are found in nature. It soon came to the point that teachers of biology ignored systematic work as not worthwhile and today very few of the biology teachers in colleges and universities are capable of teaching systematic botany. At first the more level-headed teachers told their students that they could pick up systematic botany when they were out of the class room. How large a per cent have done this? The fact is that a good systematist needs a long training and lots of hard work which the average ecologist or geneticist can not afford after leaving the class room. My advice to ecologists is to take an intelligent interest in the species they are dealing with and make friends with capable systematists who will help them. You join together and thrash out your ecological problems. It is just as essential to thrash over the species problems. Ecologists often help the systematist. Going at it that way you will find the difficulties fast disappearing.

During the time ecology has been in the making warfare has been just as serious amongst the believers in the "European code" and the "American code." Fortunately this difficulty is on the mend. The "splitters" and the "lumpers" have also had their innings much to the advantage of sane systematic work but it has also had its disadvantages which the systematist has found a hard time to steer a correct course through. The "splitters" have helped to bring forward many fine species which the old school has been forced to accept. While the "lumpers" with help from geneticist, ecologist and chemist have shown that the slogan put forward by the "splitters", if any difference is seen make it specific, soon puts the splitter where he can not recognize his own species. An intelligent study of a species both in field and herbarium gives the best results. Often raising allied or like forms in the garden will help clear up the problem. Then again many plants should be hybridized and the results studied. Conclusion: Study your plants systematically. Get the best council from systematists. Don't be lumpers, don't be splitters but find out the facts. Forget ecological species.

Forsling: It is advisable that there be a nationwide list of common names rather than a regional or local list. This need not restrict the use of long established local names for a reasonable area which may not agree with a nationwide name. In such instances the local name may be given as a synonym for local use if desired.

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COMPILATION AND ANALYSIS OF RANGE RESEARCH DATA

R. S. Campbell, Chairman

Campbell: The main emphasis at this meeting has been on methods of collecting range research data. This emphasis is justified fully by our need for development and refinement of methods, but we must remember that the collection of data is by no means our objective. Really there are six steps which constitute our job in research. They are: the careful planning and laying out of needed projects, the collection of data, compilation, a thorough analysis, convincing publication, and finally the follow through to see that the results are applied. We in range research and especially in the Forest Service have been prone to spend too much time in the collection of field data. As a result, there has been far too little time spent on the other steps and the completion of our real job. I would like to suggest that at our next meeting we plan to spend more time in the discussion of methods of compilation and analysis of data than is available at this meeting.

F. X. Schumacher: I was very much interested in your discussions of methods appropriate in ecological investigations, particularly in the talks by Doctors McGinnies and Hanson, for these had a bearing upon the use of the statistical method in ecology. As I am interested in the application of the statistical methods to forestry, we have, no doubt, many problems in methodology in common. May I ask, though, that you bear with me in my ignorance of ecology, for the last three days of your discussions have made evident to me that that ignorance is enormous.

I would like to say a few words about sampling in its simplest form -- that of counting plots. I should like to set before you a few definitions, then play a game of chance, and finally apply this game of chance to an actual problem in forestry.

Definitions

When a statistic (e.g. a mean) has been obtained, it is often important to know how much certainty may be attached to it; that is, can the data from which it is calculated be considered a random sample of a larger set of similar data.

(1) A Statistical Population or Universe: A set of things, or persons, one or more of whose characteristics is to be studied quantitatively.

Should I be interested in the growth of these aspen stands around us, the universe might be defined as "aspen in pure stands, Central Utah." I think it becomes at once evident, that a rigid definition of the thing to be studied, the universe, keeps one within the bounds of the problem, with little likelihood at the end of the investigation to generalize beyond the confines of the universe dealt with.

(2) A Statistical Sample: A selection of one or more individuals from a statistical universe, provided the selection is done in such a way that any one individual in the universe is as likely to be selected as any other. Such a sample is a random sample.

Usually in statistics it is only a selection from a universe with which we can deal, and the question arises as to whether the selection can be considered as a sample.

Evidently any conclusions we draw, are drawn after an analysis of the selection. Therefore, unless the selection can be considered as a random sample, we are not warranted in stating that our conclusions apply to the universe.

Chance

Consider an event to be a happening which must be either a success or a failure. The toss of a coin 10 times makes ten events and the number of times heads turn up may be called so many successes.

Let

n = the number of individual events

and a = the number of successes in events

Evidently then, the chance of a success in a single event is

$$\frac{a}{n} = p$$

and the chance of failure in the same event is $1 - p = q$, where $p + q = 1$ the particular event considered.

Now chance implies lack of certainty: Therefore we may ask, what is the logical range in expectation in the number of successes in a given number of events?

By mathematical reasoning Bernoulli has shown that the logical range from the expected value may be expressed

$$\sigma = \sqrt{n\,p\,q}$$

in which σ = the standard deviation, the deviation from the expected value which in two-thirds of the events should not be exceeded.

Consider the proposition: If 100 balls are drawn from a bag which contains a great many white and red balls in equal numbers, what deviation from 50 may be logically expected in the number of white balls drawn?

By the Bernoullian theory,

$$\sigma = \sqrt{100 \times 0.5 \times 0.5}$$
$$= 5$$

that is, the chances are two out of 3 (or 2 to 1) that the number of white balls drawn will be between 45 and 55 or, more succinctly,

$$\text{Mean} = 50 \pm 5$$

Now we naturally want to know, does this theory fit the facts in such a game of chance?

Such experiments have been made many times in drawing cards from a pack, in tossing coins or dice and in drawing balls from urns. The following experiment by Westergaard illustrates the check of fact with theory. From an urn containing white and red balls he made 100 sets of drawings (with replacement after each draw). Following were the results:

Number of White Balls in 100 Drawings

Number of white balls	Number of sets
33-35	1
36-38	0
39-41	5
42-44	8
45-47	15
48-50	25
51-53	19
54-56	16
57-59	8
60-62	2
63-65	1
	100

The actual mean = 50.1 and the actual standard deviation = 5.33. Theoretically these figures should be (see above) 50 and 5 respectively.

Application

May I now ask: is this simply an amusing pastime or does the Bernoullian theory have a real application to certain phases of ecological investigation? I should like to illustrate its use in a forestry problem because I must plead ignorance of ecology; and trust you gentlemen to see a possible analogy in your field.

The Forest Service is at present engaged in estimating the hardwood resources in the Mississippi bottomlands. Among the things wanted is the area in forest land. In two Louisiana parishes already studied ten strips three miles apart were run westerly across the county. At 660 foot intervals along the strips, a sample plot was measured if it fell in the forest. If the 660 foot point fell in the open a tally was made "non-forest plot". Carrying on in this way netted a total of 1900 plots of which (if I remember correctly) 1140 were forest plots. The question now is: Does the game of chance work in such a way that we can estimate reasonably closely, the area in forest land and non-forest land in the two counties?

We have:

500,000 acres in the two counties. This is very close to the best estimate of area obtainable:

Also $\frac{\alpha}{n} = \frac{1140}{1900} = .600 = p$ the chance of success of a single plot, i.e., the probability that a single plot is a forest plot.

$$\begin{aligned} \text{Hence } q &= 1 - p \\ &= 1 - .600 \\ &= .400 \end{aligned}$$

And by the Bernoullian theory

$$\begin{aligned} \sigma &= \sqrt{1900 \times .6 \times .4} \\ &= 21.9 \text{ plots} \end{aligned}$$

or slightly over 1 per cent of the 1900 land plots. Therefore we concluded that the chances are about 2 to 1 that our estimate of the forest land area of the two counties concerned, is within 1 per cent of the true land area or 2 per cent of the true forest area, provided the sampling method used may be considered random sampling.

This last point we are now investigating, because it is not at all evident to us that the sampling method used may be considered random sampling for forest area determination. On the other hand, had the plots along the strips been spaced at intervals equal to the distance between strips - say one mile - we would have had a checkerboard system of sampling. Then only, we should have had full confidence at the start, in the direct application of the Bernoullian theory. As it is we have yet to find out whether our dice are loaded.

SOME STATISTICAL METHODS FOR RANGE STUDIES

By George Stewart
Senior Ecologist, I.F.& R.E.S.

It is known that errors influence the data resulting from experimental investigations. Such errors may for the sake of convenience be divided into three classes: (1) Mechanical errors due to faulty methods; (2) soil heterogeneity; and (3) experimental errors due to lack of standardized behavior in the plants or animals used. In the physical sciences soil heterogeneity is also ordinarily not a factor; and the last error either does not occur at all or else is very small. Whenever living organisms are used in an experiment, this last sort of error, which might be termed "biological", but which here is designated as "experimental", introduces uncontrollable errors of considerable magnitude. In other words living organisms are alive.

It is the business of the research worker to reduce the mechanical error to such an extent that it does not materially influence the data. The chemist and the physicist have in the main only this correction of faulty methods. They have specialized in the reduction of such error, as for example in the determination of atomic weights and the study of electrons, until it is almost non-existent. They use delicate balances, control temperatures to within three or four thousandths of a degree, purify the air used, and go to almost endless trouble to remove impurities from the element being studied. The amount of light admitted and the possibility of stray magnetic fields often enter into their problems. Though with range work such refinement is not required, some of the larger errors of method must be avoided to permit satisfactory work. The following points are thought to be worthy of consideration:

1. Different workers should occasionally check each other, (a) to cause judgments to conform reasonably, and (b) to see that a new worker really understands the process.

2. Instruments of a complicated nature must be tested to make sure they are in good working order. Strange as it may seem, new instruments require especial care in this respect.

3. The season of the year, the time of day, or the recency of stormmay deserve consideration.

4. Measurements require attention in two respects: (a) they should really be measurements of a given degree of accuracy and (b) the points of beginning and of ending should be clear in the mind of him who gathers the data.

No good agronomist or plant breeder now overlooks the vast influence of variations in the productive power of small areas of the soil. Whereas gross differences are easily seen, the more minute variations are

not at all visible. Harris [1] made clear the occurrence of such differences and invented an approximate method of measuring the soil heterogeneity. Many years of field experimentation has revealed the urgency of plat replications as a method of reducing the effects of this lack of uniformity even in the visibly most uniform of soils. This introduces a problem by itself, and since this paper deals with it only casually, it will perhaps suffice for the present to say that under field crop conditions three plats of the same treatment are required and four is more nearly satisfactory. Our range soils are even more variable than are farm soils.

However, after all these precautions have been taken, there remains a measurable amount of error, resulting from only partial control of soil heterogeneity and from the variability of the living plants or animals. A considerable study of variability in farm animals in their response to feeding was made by Mitchell and Grindley [2] at Illinois. They found a residual error of 14 to 17 per cent in cattle, sheep, and hogs after such correctable errors as age, sex, and breed has been overcome. They reported the utter futility of experiments in which this error was not recognized. Single lots of animals on the same feeding treatment were not only useless but misleading. They concluded that it was also necessary to have large numbers of animals (12 to 40) in each lot. They also proceeded to show how to calculate the variability for such experiments. Agronomists, who have a problem similar to that of the range, usually follow the work of Hayes and Garber [3] not because there are no other treatises but because it gathers all commonly needed statistics into one chapter. It is also easy for the amateur statistician to follow. In the statistical methods suitable to plant work here presented, methods and the system of notation used by Hayes and Garber are here followed. An effort is herewith made to show the application of such methods to range studies by presenting an actual problem and working it through.

Statistical methods are almost endless and an effort to introduce the complicated forms would fail of its own weight. Let us regard statistics as a guide to be used in planning an experiment and as a tool to be used in studying the data procured. Much is purposely omitted to avoid bewildering the beginner. A few of the simpler and highly useful methods may be listed as follows:

A - Constants of variation
  1. Standard deviation
  2. Probable error
    (a) Error of a plat series
    (b) Error of paired treatments

1/ Harris, J. A., Practical universality of field heterogeneity as a factor influencing plot yields. Jour. Agr. Research 19:279-314 (1920).

2/ Mitchell, H. H., and Grindley, H. S., The element of uncertainty in the interpretation of feeding experiments. Ill. Bul. 165:2163-579 (1913).

3/ Hayes, H. K. and Garber, R. G. "Breeding Crop Plants." McGraw-Hill, New York, 1927. Second Edition. See Biometrical Methods - Chap. III.

3. Coefficient of variability.

B - Constants of correlation
  1. Correlation coefficient (r)
  2. Correlation ratio (η = eta)

C - Interpreting the results obtained by calculation.

Now for a concrete problem to illustrate each case.

At Dubois, Idaho on the U. S. Sheep Experiment Station range are nine 80-acre grazing paddocks under study. Originally there was one quadrat in each paddock. In view of the vast soil heterogeneity this number has recently been increased to four. On these quadrats, among other things, the grass area was charted and are here taken for study. In Table 1 are presented the grass area on each quadrat, the mean area for each paddock and the manner of calculating the three constants of variation, (1) standard deviation, (2) probable error of a plat series, and (3) the coefficient of variability.

In the first columns of Table 1 the paddock numbers, the grass areas for each quadrat, and the mean of the four quadrats for each paddock are set down. The difference between the grass area of each quadrat, and the mean of the four quadrats is obtained and set in the column marked D (= deviation from mean) while the squares of these numbers are set down in the next column D^2. These are then added and the standard deviation (σ) calculated according to the formula.

$$\sigma = \sqrt{\frac{\Sigma D^2}{n}}$$

Σ = is a sign used to mean summation.

n = the number of individual quadrats.

Substituting in the formula, we have

$$\sigma = \sqrt{\frac{324,574.00}{44}} = \sqrt{7376.6818} = 85.8876 \text{ sq. cm. of grass}$$

That is, when properly equated there is a random deviation of 85.9 sq. cm. of grass in each quadrat. Now to obtain the probable error of each individual quadrat - P. E. = .6745 x σ .

$$\text{P. E.} = 85.8876 \times .6745 = 57.93 \text{ sq. cm.}$$

Coefficient of variability (%) = $\frac{\sigma 100}{M} = \frac{85.9}{324.4} = 26.48\%$

For the mean of each paddock

$$\text{P. E.} = \frac{.6745 \times \sigma}{\sqrt{n}} = \frac{.6745 \times 85.8876}{\sqrt{4}} = 28.96 \text{ sq. cm.}$$

Thus replication reduces the error of the mean according to the square root of the number of replications.

Table 1. Method of calculating constants of variation (standard deviation, probable error, and coefficient of variability) on grass area on quadrats at the U. S. Sheep Experiment Station at Dubois, Idaho, Part I. Straight deviation method. Part II. Hayes' percentage deviation from the mean method.

Plot	V	M	Part II			Part I	
			%	D		D	D^2
P1E1	504)	512.5	98.3	1.7	2.89	8.5	72.25
	566)		110.4	10.4	108.16	53.5	2862.25
	424)		82.7	17.3	299.29	88.5	7832.25
	556)		108.5	8.5	72.25	43.5	1892.25
Pi	382)	447.5	85.4	14.6	213.16	65.5	4290.25
	342)		76.4	23.6	556.96	105.5	11130.25
	668)		149.3	49.3	2430.49	220.5	48620.25
	398)		88.9	11.1	123.21	49.5	2450.25
P2	164)	109.25	150.1	50.1	2510.01	54.75	2997.5625
	75)		68.6	31.4	985.96	34.25	1173.0625
	88)		80.5	19.5	380.25	21.25	451.5625
	110)		100.7	.7	.49	.75	.5625
P3	275)	287.5	95.7	4.3	18.49	12.5	156.26
	290)		100.9	.9	.81	2.5	6.25
	161)		56.0	44.0	1936.00	126.5	16002.25
	424)		147.5	47.5	2256.25	136.5	18632.25
P4	98)	225.25	43.5	56.5	3192.25	127.25	16192.5625
	331)		146.9	46.9	2199.61	105.75	11183.0625
	281)		124.8	24.8	615.04	55.75	3108.0625
	191)		84.8	15.2	231.04	34.25	1173.0625
P5	286)	308.5	92.7	7.3	53.29	22.5	506.25
	205)		66.5	33.5	1122.25	103.5	10712.25
	437)		141.7	41.7	1738.89	128.5	16512.25
	306)		99.2	.8	.64	2.5	6.25
P6	641)	445.25	144.0	44.0	1936.00	195.75	38318.0625
	197)		44.2	55.8	3113.64	248.25	61628.0625
	478)		107.4	7.4	54.76	32.75	1072.5625
	465)		104.3	4.3	18.49	19.75	390.0625
P7	409)	380.5	107.5	7.5	56.25	28.5	812.25
	392)		103.0	3.0	9.00	11.5	132.25
	319)		83.8	16.2	262.44	61.5	3782.25
	402)		105.7	5.7	32.49	21.5	462.25

Table 1 (Cont.)

Plot	V	M	Part II %	D		Part I D	D^2
P7E1	397)	476.5	83.3	16.7	278.89	79.5	6320.25
	438)		91.9	8.1	65.61	38.5	1482.25
	454)		95.3	4.7	22.09	22.5	506.25
	617)		129.5	29.5	870.25	140.5	19740.25
P8	157)	130.25	120.5	20.5	420.25	26.75	715.5625
	125)		96.0	4.0	16.00	5.25	27.5625
	100)		76.8	23.2	538.24	30.25	915.0625
	139)		106.7	6.7	44.89	8.75	76.5625
P9	275)	245.5	112.0	12.0	144.00	29.5	870.25
	289)		117.7	17.7	313.29	43.5	1892.25
	258)		105.1	5.1	26.01	12.5	156.25
	160)		65.2	34.8	1211.04	85.5	7310.25
Mean of all		324.4			30,481.31		$\frac{324,5\cancel{1}7 4.0000}{44}$

$$= \sqrt{7376.6818}$$

$$\sigma_{I} = 85.8876$$

692.757

$$\sigma = \frac{30,481.31}{44} = \cancel{7,337.16}$$

$$\sigma = 26.32\%$$

$$P.E. = 17.75$$

$$P.E.m. = \frac{17.75}{\sqrt{4}} = 8.875$$

$$P.E. = \frac{57.93}{\sqrt{4}} = 28.96$$

$$C.V.(\%) = \frac{85.8876}{324.4}$$

$$= 26.48\%$$

Hayes and Garber recommend a slight variation of this method which involves changing the values to percentage of the mean and using the percentages instead of the actual values. (See Part I, Table 1.)

The mean error when worked through in this fashion is 28.80 per cent, practically identical with that obtained by the straight deviation method. However, the probable errors for the straight deviation method will be the same for each paddock while for the percentage-deviation method the error expressed in per cent will be the same; but the concrete value of the errors will differ according to the absolute value of the mean. This difference is brought out in Table 2 where the results are set up side by side.

Table 2. Comparison of the results obtained on the Dubois Sheep Station paddocks by calculating the data in two ways, (1) straight deviation method and (2) Hayes' percentage deviation from the mean.

Paddock	Straight Deviation			Percentage Deviation		
	Grass Area sq. cm.		Probable Error sq. cm.	Grass Area sq. cm.		Probable Error sq. cm.
P 1 E 1	512.5	±	28.96	512.5	±	45.5
P 1	447.5	±	28.96	447.5	±	39.7
P 2	109.25	±	28.96	109.25	±	9.7
P 3	287.5	±	28.96	287.5	±	25.5
P 4	225.25	±	28.96	225.25	±	20.0
P 5	308.5	±	28.96	308.5	±	27.4
P 6	445.25	±	28.96	445.25	±	39.5
P 7	380.5	±	28.96	380.5	±	33.8
P 7 E 1	476.5	±	28.96	476.5	±	42.3
P 8	130.25	±	28.96	130.25	±	11.6
P 9	245.5	±	28.96	245.5	±	21.8
Mean	324.4	±	28.96	324.4	±	28.80

Whether to use one method or the other would depend on whether the deviations in the paddocks with the four quadrats averaged approximately the same absolute values as they might do, or the same percentage values as they do in this case. This case warrants the use therefore of Hayes' percentage deviation method and has the attractive feature of giving a series of probable errors that differ from each other.

Now, do the good-grazed paddocks bear significantly more grass than the poor-grazed areas? Does protection increase the grass area? Set the figures down thus:

#1	447.5 ± 39.7		#1 - E 1	512.5 ± 45.5
#2	109.25 ± 9.7		#1	447.5 ± 39.7
	338.25 ± 40.87			65.0 ± 60.385

D/P.E. = 8.3 1.08
Probability Billion : 1 1.15 : 1

Probability is obtained from a table on p. 42, Hayes and Garber.

The probable error of a difference as just obtained between paddocks #1 and 2, and # 1 E 1 and #1 is calculated as follows:

$$\text{P.E. of Dif. (or Sum)} = \sqrt{E^2 + E^2}$$

$$\text{Here } \sqrt{(39.7)^2 + (9.7)^2} = \sqrt{1576.09 - 94.09}$$

$$= \sqrt{1670.18} = 40.87$$

The difference is now divided by the error $\frac{338.75}{40.87} = 8.3$

Based on the normal curve, the Hayes and Garber table shows the number of times the trial would have to be repeated to get a result as great as this due to chance alone.

Sometimes in range experimental work the number of comparisons may be small. A method, known as "Student's" method, has been devised to handle such cases, and serves very well if the cases are paired. Pairing is not uncommon in range studies, as for example one protected quadrat paired with a grazed one. Such a pair means little by itself due to great soil heterogeneity, but a series of pairs are capable of being analyzed largely in view of their consistency. Here the Dubois quadrats are paired, 1930 against 1931, to see if there is seasonal difference. Three groups of eight quadrats each are available for study and are shown in Table 3 under (1) protected quadrats, (2) grazed paddocks in good condition, designated as "good-grazed", and (3) grazed paddocks in poor condition ("poor-grazed"). Twenty or fifty pairs would be better but the method is available for small numbers whenever pairing can in a real sense be brought about. Here the grass area in 1930 is paired against the grass area in 1931. It might be more sensible to compare quadrats after three years, or five years, but the method is the same, just so legitimate pairing is possible.

The method of calculation is summarized and a table given in Hayes and Garber, pp. 86-92. The pairs of data are set on the same line in adjacent columns marked A and B. Deviations are obtained, with + and - signs carried and noted in column D (deviations). When this column is summed, the algebraic sum is taken, that is, the + and - signs are observed. The deviations are then squared for the D^2 column, the signs disappearing as a result of squaring. The summed D and D^2 columns are divided by n (n = the number of paired results used), and the standard deviation obtained. Table 3 gives the figures and method of calculation. The mean of the deviations is divided by the standard deviation to obtain "Z". The table in Hayes and Garber then permits one to read "odds", for or against a result, by finding "Z" in the far left-hand column and n at the head of the columns (n = the number of paired results), eight in my calculations.

Table 3 shows that the odds are 54.4 : 1 that the good grazed plats are better in 1931 than in 1930. With the protected plats the odds are 3.11 : 1 that they were poorer in 1931. The poor plats give odds of 1.8 : 1 that 1931 is better. Odds of 20 or 30 to 1 are regarded as significant.

Coefficients of variability is merely an expression of standard deviation in terms of percentage. Trees are taller than grasses; trees are measured in feet whereas grasses are measured in centimeters. Trees differ more in height than do grasses. But are they more variable, on a percentage basis? The standard deviation is divided by the mean height of each and the coefficient of variability obtained. Trees are no more variable than grasses. A method of studying plants by using the coefficient of variability is shown in Table 4. The plants used are alfalfa, but height, or some other character, of range plants may use the method.

Table 3. Method of calculating "odds" by "Student's" method when the grass areas in 1930 are paired against those of 1931 showing method of analyzing quadrat data capable of being paired; The data are from the U. S. Sheep Experiment Station at Dubois, Idaho, arranged in three groups: (a) protected quadrats, (b) "good-grazed" quadrats, and (c) "poor-grazed" quadrats.

A 1930	B 1931	D	D^2	
		Protected		
504	607	103	10609	$\sqrt{6929.6-(22.4)^2} = \sqrt{6527.84}$
566	499	- 67	4489	501.76
424	473	49	2401	
556	416	-140	29600	= 80.80
397	417	20	400	$\frac{22.4}{80.8} = .2772$
438	414	- 24	576	
454	403	- 51	2601	
617	548	- 69	4761	Odds = 3.11 : 1
494.5	472.125	179	55437	
		22.4	6929.6	
		Good Grazed		
382	538	156	24336	$\sqrt{4,833.875 - (48.625)^2}$
342	421	79	6241	2364.3906
668	685	17	289	
398	429	31	961	$\sqrt{2469.4844} = 49.6939$
409	392	- 17	289	$\frac{48.625}{49.6939} = .9785$
392	403	11	121	
319	366	47	2209	
402	467	65	4225	Odds 54.4 : 1
414.0	462.625	389	38671	
		48.625	4,833.875	
		Poor Grazed		
164	122	- 42	1764	$\sqrt{315.375 - 6.8906} = \sqrt{308.4844}$
75	85	10	100	
88	94	6	36	= 17.3345
110	116	6	36	
157	176	19	361	$\frac{2.625}{17.3345} = .1514$
125	137	12	144	
100	101	1	1	
139	148	9	81	Odds 1.8 : 1
119.75	122.375	21	2523	
		2.625	315.375	

Table 4. Comparison of parent alfalfa plants and selected offspring of 20 to 40 individual plants in each row of offspring to find if selection is decreasing variability.

C.V. %	Height of alfalfa plant rows (Inches) 14	16	18	20	22	24	26	28	30	32
					Parental Plants					
18								I		
21					1		3	1	1	
24					1	1				
27			1							
					Progeny Rows					
6						1				
9					1	1	4	3		
12				3	2	5	4	1		
15				3	4	5	5	1		1
18				3	5	5	2	2		
21	1		2	5	6	5	1			
24		1	2	4	5	5				
27		1	3	2	1	1	2			
30			1	1		1				
33										
36			1							
39			1							

A study of Table 4 shows the parents to have a range of 18 to 27 per cent variability. Some progeny rows are shown to be almost pure-breeding for one height or another. Other rows are extremely variable whereas the majority of the population resemble the parents in height range and in variability of 130 progeny rows, 24 had coefficients of variability of 12 per cent or smaller and 10 were 9 per cent or smaller. Selection seems, therefore, to purify strains of alfalfa rather effectively so far as height is concerned. The method is available for such range studies as twig growth, plant height, effect of different seasons on growth rate, or height, or earliness, or percentage composition.

CORRELATIONS

In the erosion survey on the Boise Forest, it was not clear which factors most definitely affected the rate of erosion. Among others, correlations were calculated to study erosion in relation to inaccessibility to livestock. In Table 5 are presented the pertinent figures for the calculation of the coefficient of correlation, which for shortness is called "r". The essential point is to arrange the data in 5 to 15 classes (preferably near 10) according to percentage inaccessibility on one side and according to erosion classes on the other. The numbers are cross multiplied by any one of three or four methods. Since one of these methods is suitable for machine calculation, Hayes and Garber present that one, and it is followed here as most feasible. Each step is simple but since there are several steps, every one just follows a prepared

sheet, or the one in Hayes and Garber. When the various columns $\frac{\Sigma X}{N}$, $\frac{\Sigma X^2}{N}$, $\frac{\Sigma Y}{N}$, $\frac{\Sigma Y^2}{N}$, and $\frac{\Sigma XY}{N}$ are calculated, and they are merely simple routine, all that is left is to substitute in the formula .

$$r = \frac{\frac{\Sigma XY}{N} - \bar{X}\,\bar{Y}}{\sqrt{\frac{\Sigma X^2}{N} - \frac{(\Sigma X)^2}{(N)}}\;\sqrt{\frac{\Sigma Y^2}{N} - \frac{(\Sigma Y)^2}{(N)}}}$$

every step of which is readily done on the calculator, even to extracting the square roots. When this was done for erosion classes correlated with percentage inaccessibility. $r = -.4694 \pm .0153$ which indicated high correlation. Sometimes, however, r is not the best method to use to study corelationships, as when one group of the data is in categories instead of in measured classes. The erosion classes here used are categories. In the same table the method of calculating the correlation ratio (η = eta) is shown. The columns $\frac{\Sigma X}{N}$, $\frac{\Sigma X^2}{N}$, $y\bar{X}$, $y\bar{X} - \bar{X}$, $(y\bar{X} - \bar{X})^2$, and $f\ (y\bar{X} - \bar{X})^2$ are even easier to get than the ones for r. The columns $\frac{\Sigma X}{N}$ and $\frac{\Sigma X^2}{N}$ are the same as for r. When the columns are calculated the last one is summed. The formula to us is

$$\eta = \sqrt{\frac{\frac{\Sigma f(y\bar{\bar{X}} - \bar{X})^2}{N}}{\sqrt{\frac{\Sigma X^2}{N} - \frac{(\Sigma X)^2}{N}}}}$$

In this case $\eta = .5034 \pm .0146$ a still higher correlation ratio. Sometimes η is much higher than r. It then indicates that the trend of the correlation (regression line) is indirect, spotted, or curvilinear, or at any rate not linear. The significance of this difference is tested by use of a formula for Blakeman's test.

$$\text{Blakeman's Test} = \frac{\eta^2 - r^2}{\text{P.E. of } \eta^2 - r^2}$$. The probable error is calculated by the formula

$$\text{P.E. of } \eta^2 - r^2 = 2 \times \frac{.6745}{\sqrt{n}} \times \sqrt{\eta^2 - r^2} \quad \times \sqrt{(1 - \eta^2)^2 - (1 - r^2)^2 + 1}$$

In our problem

$$\frac{\eta^2 - r^2}{\text{P.E. of } \eta^2 - r^2} = \frac{.0331}{.006945} = 4.766019 = \text{Blakeman's Test.}$$

Since $\eta^2 - r^2$ is appreciably more than three times its error, this is said to be rather significant evidence of more correlation than is measured by r.

Table 5a

METHOD FOR CORRELATION COEFFICIENT (r)

XY	Y^2	Y	f	5	4	3	2	1	Y		
				4	3	2	5	1			
					(25)	(16)	(9)	(4)	(1)		
				Erosion Class							Percentage inaccessibility
2035	6247	2035	744	19	73	482	32	138	1	(1)	0
442	645	221	91	1	9	49	1	31	2	(4)	10
405	359	135	64	0	4	29	1	30	3	(9)	20
340	221	85	44	1	2	15	1	25	4	(16)	30
205	121	41	18	1	1	8	0	8	5	(25)	40
456	198	76	38		3	14	1	20	6	(36)	50
252	96	36	17		1	8		8	7	(49)	60
168	33	21	17			2		15	8	(64)	70
99	23	11	7			2		5	9	(81)	80
1820	290	182	146			18		128	10	(100)	90
6222	8233	2843	1186								

	Total	5	4	3	2	1
f	1186	22	93	627	36	408
X	3390	30	141	1121	47	2051
X^2	21,294	64	359	4,365	97	16,409
XY	6222	150	564	3363	94	2051

$$\frac{\Sigma X}{N} = \frac{3390}{1186} = 2.8583 = \bar{X}$$

$$\frac{\Sigma X^2}{N} = \frac{21,294}{1186} = 17.9545$$

$$\frac{\Sigma Y}{N} = \frac{2843}{1186} = 2.3971 = \bar{Y}$$

$$\frac{\Sigma Y^2}{N} = \frac{8233}{1186} = 6.9418$$

$$\frac{\Sigma XY}{N} = \frac{6222}{1186} = 5.2462$$

$$\left(\frac{\Sigma X}{N}\right)^2 = 8.1699$$

$$\left(\frac{\Sigma Y}{N}\right)^2 = 5.7461$$

$$\bar{X}\,\bar{Y} = 6.8516$$

$$r = \frac{\frac{\sum XY}{N} - \bar{X}\,\bar{Y}}{\sqrt{\frac{\sum X^2}{N} - \left(\frac{\sum X}{N}\right)^2}\ \sqrt{\frac{\sum Y^2}{N} - \left(\frac{\sum Y}{N}\right)^2}}$$

$$r = \frac{5.2462 - 6.8516}{\sqrt{17.9545 - 8.1699}\ \sqrt{6.9418 - 5.7461}}$$

$$= \frac{-1.6054}{\sqrt{9.7846}\ \sqrt{1.1957}} = \frac{-1.6054}{3.1280 \times 1.0934} = \frac{-1.6054}{3.4202} = -.4694$$

$$\text{P.E. } r = \frac{.67449\,(1-r^2)}{\sqrt{n}} = \frac{.67449\,(1-(.4694)^2)}{\sqrt{1186}} = \frac{.6749\,(1 - .2203)}{34.44}$$

$$= \frac{.67449 \times .7797}{34.44} = .0153$$

$$r = -.4694 \pm .0153$$

$$r = 30.7 \text{ times P. E.}$$

METHOD FOR CORRELATION RATIO (η)

f	$\overline{yX}$	$\overline{yX}-\overline{X}$	$(\overline{yX}-\overline{X})^2$	$f(\overline{yX}-\overline{X})$
408	5.0270	2.1687	4.7033	1918.9464
36	1.3056	1.5527	2.4109	86.7924
627	1.7879	1.0704	1.1458	718.4166
93	1.5161	1.3422	1.8015	167.5395
22	1.3636	1.4947	2.2341	49.1502
1186				2940.8451

$$\eta = \frac{\sqrt{\dfrac{\Sigma f(\overline{yX}-\overline{X})^2}{N}}}{\sigma} = \frac{\sqrt{\dfrac{2940.8451}{1186}}}{3.1280} = \frac{\sqrt{2.4796}}{3.1280}$$

Note: $\sigma = \sqrt{\dfrac{\Sigma X^2}{N} - \left(\dfrac{\Sigma X}{N}\right)^2}$

$$\eta = \frac{1.5747}{3.1280} = .5034$$

$$\text{P.E.}\ \eta = \frac{.67449 \times (1-(.5034)^2)}{34.44} = \frac{.67449 \times .746588}{34.44}$$

η = $.5034 \pm .0146$

η = 34.5 times P. E.

Blakeman's Test

$$\text{P. E. of } \eta^2 - r^2 = 2 \times \frac{.67449}{\sqrt{n}} \times \sqrt{\eta^2 - r^2} \times \sqrt{(1-\eta^2)^2 - (1-r^2)^2 + 1}$$

$$= 2 \times \frac{.67449}{34.44} \times \sqrt{.2534 - .2203} \times \sqrt{.557394 - .607932 + 1}$$

$$= 2 \times \frac{.67449}{34.44} \times \sqrt{.0331} \times \sqrt{.949462}$$

$$= .039168 \times \underbrace{.181960 \times .974403}_{.177302}$$

P. E. = .006945

$$\text{Blakeman's test} = \frac{\eta^2 - r^2}{\text{P.E.}} = \frac{.0331}{.006945} = 4.766019$$

Table 6 is presented to show on one hand the appearance of a very high correlation about which there is no statistical doubt and Table 7 an unsatisfactory correlation from the standpoint both of size of the constant and from the number of cases included.

Table 6. Scatter diagram of a correlation between the percentage of organic matter in soils from the Boise and Sawtooth Forests and their water-holding capacity, showing the appearance when there is a high linear correlation (r).

Organic Matter In Soil	Water-Holding Capacity: 30-35	35-40	45	50	55	60	65	70	75	80	85	90	95	100	105	f
0 - 1	4	7	1	1												13
1 - 2		2	7	3	5											17
3		1	8	14	3	1	1									28
4		1	4	8	3	2										18
5			2	3	4	2	1									12
6						2	2		2							6
7	1			3	2	2			1							9
8						1		3			1		1			6
9							2	2			1		1			6
10						1		1			2	1				5
11									1	1						2
12																0
13												1				1
14											1					1
15																0
16											1				1	2
17											1					1
f	5	11	22	32	17	11	6	6	4	1	7	2	2	0	1	127

$$r = +.83445 \pm .0182$$

$$r = 45.8 \text{ times P. E.}$$

$$\eta = .8631 \pm .0132$$

$$\eta = 66.9 \text{ times P. E.}$$

Table 7. Scatter diagram of a correlation between percentage profits and months of all labor used, showing appearance of a poor correlation and a too small number of ranches.

Profits	Months All Labor 25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	f
-3	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	1
0	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	2
3	.	.	.	.	1	2	.	1	.	.	.	.	1	.	.	.	5
6	.	.	.	1	1	1	.	1	.	.	.	.	.	.	.	.	4
9	.	.	1	2	.	.	.	.	.	.	2	1	.	.	.	.	7
12	.	1	.	1	1	1	.	.	.	.	.	.	.	.	.	.	4
15	1	.	1	1	1	.	.	1	.	.	1	.	1	1	.	.	8
18	.	.	1	.	1	.	1	.	1	.	.	.	1	.	1	.	6
21	.	.	1	.	.	.	.	.	.	.	.	1	2	.	.	.	4
24	.	.	.	.	.	1	.	1	.	.	.	.	.	.	.	1	3
27	.	.	.	1	.	.	1	.	.	.	.	.	.	.	.	.	2
30	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	1
33	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	1
36	.	1	.	.	.	1	.	.	.	.	.	.	.	.	.	.	2
39	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1
f	1	2	4	9	5	7	2	4	1	0	4	3	5	1	1	1	51

$r = -.1009 \pm .093$

$r =$ 1.1 times its P.E.

$\eta = .5389 \pm .067$

$\eta =$ 8.0 times P.E.

B. Test = 4.3044

Interpreting Calculated Statistical Constants

The standard deviation (σ) shows the size of variations to be expected. It is used, however, principally as a basic figure from which to derive the probable error and the coefficient of variability, one or both of which is ordinarily used in the final array of calculated results. The coefficient of variability is ordinarily used to compare variability of one generation with that of another as was done in the selection studies of alfalfa. It may be used to compare one site with another, one season with another, - in fact to compare any character where variability is found under two conditions. If the values to be compared are close, the probable error of each is obtained according to formula in Hayes and Garber. This now falls into the probable error studies, wherein it is best to calculate that the difference is so many times the error. Agronomists quickly recognize that when the difference is three times the error, the odds are 22 to 1. This means that only once in 23 times would a difference as great as the one secured be obtained due to chance alone. A ratio of less than three times the error is not given much weight, but one greater than three times the error makes the probability mount very rapidly, - 142 to 1 when the ratio is four times the error, and 1350 to 1 when the ratio is five times the error. Beyond five times the error, the probability quickly mounts into the millions. Just what probability one must have to be sure of his results depends on the person. Some accept three or slightly more, that is, they are satisfied with chances of 20 or 30 to 1 in their favor. Personally I feel much safer when the probability is 50, 100, or 150 to 1 that my result is a really significant one, that is, I like to get ratios of 3.5 to 4 or more times the error. (See Hayes & Garber, p. 42 for table.)

In correlations the problem of interpretation is double, that is, the size of the constant as well as its ratio to the error deserves care. Some workers feel that the size of a correlation constant must be at least .4 to be valuable but others while liking the constants large will accept them in the neighborhood of .2 if they are consistent, that is, if they get them to repeat. Naturally, really high correlations add to the assurance of the result. The ratio of the constant to the error bears the same relation as discussed previously for error. Four or more times the error is highly significant. Blakeman's test of four or more indicates that there is more correlation than r measures, unless one or two far-outlying individuals greatly influence the result as they would do in calculating . Table 7 shows a case where this is true. One needs to be on guard for too few and for over-erratic cases.

As in all things, good sense helps to avoid pitfalls. Finally, one swallow is not a season, or a few rain drops a flood. In other words, statistical data should be cumulative. A few cases, however good, are better thought of as "shoestring" gullies down which the next rain is likely to run, than as the Colorado Canyon, which can carry any flood whatsoever.

Forsling: In the statistical method of analysis the range research worker has a tool which has been very little used in the past. Range research itself is a new field and until the present perhaps has not been ready for very extensive use of statistical methods. However, the use of the method has made such an advance in many of the other biological fields that the time is at hand when range research workers should become acquainted with it and use it to the fullest extent possible.